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WORLDWIDE ANALYSIS OF MARINE 'BUNKER C' FUEL OILS.(U)

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LEVEL
WORLDWIDE ANALYSIS

OF

MARINE "BUNKER C" FUEL OILS

FINAL REPORT

ADA 096139

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OF
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FINAL REPORT

Contract No. 0-1005
Report No. MA-RD-920-81001

December 1980

Prepared for
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Washington, D.C. 20230

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Bethlehem Steel, Inc.
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Interlake Steamship, Inc.
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SUMMARY

GENERAL

This survey provides the results of physical and chemical tests performed on 150 samples of marine Bunker C fuel oil as it was bunkered aboard U.S. merchant steamships. These samples represent 75 ports of the world in 8 geographic regions as contributed by 28 participating companies.

CONCLUSIONS

The comparison of the 1976 and 1980 studies indicates an overall degradation of the quality of bunker fuels available (refer to the following table). The most dramatic degradation has occurred in vanadium levels, which rose from 40 ppm to 140 ppm. Other indications of fuel quality, such as ash, API gravity, viscosity, sulfur, and sodium, indicate that a lower quality of fuel is currently available than was available to U.S. merchant steamships in 1976.

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COMPARISON OF 1980 SURVEY TO 1976 SURVEY
AND THE INDUSTRY REFERENCE 1/

Fuel Characteristics	Symbol	Industry Standard	1976 Survey	1980 Survey
CARBON %	C	87.75	85.20	85.78
HYDROGEN %	H	10.50	11.30	10.88
NITROGEN %	N	0.15	0.80	0.33
OXYGEN % (<0.5%) ^{2/}	O	0.40	0.43	0.55
SULFUR %	S	1.20	2.97	2.60
ASH %	ASH	--	0.03	0.08
API GRAVITY @ 60°F	GRAV	--	15.1	13.65
PM FLASH POINT (0°F)	FLASH	--	192	197
VISCOSITY (SSU @ 100°F)	VISSSU	--	3264	3982
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	--	2861	3491
HEATING VALUE BTU/LB	HTVAL	18500	18780	18408
SPECIFIC WEIGHT LB/GAL	SPECWT	--	8.99	8.13
PHOSPHORUS, ppm (<30) ^{2/}	P	--	40	46
IRON, ppm	FE	--	6	10
LEAD, ppm	PB	--	1	2
COPPER, ppm	CU	--	0	0.5
CHROMIUM, ppm	CR	--	0	0.4
ALUMINUM, ppm	AL	--	2	12
NICKEL, ppm	NI	--	18	37
SILVER, ppm	AG	--	0	0
TIN, ppm	SN	--	0	3
SILICON, ppm	SI	--	2	13
BORON, ppm (<15) ^{2/}	B	--	0	15
SODIUM, ppm	NA	--	15	13
ZINC, ppm	ZN	--	0	2
CALCIUM, ppm	CA	--	30	5
SARIUM, ppm	SA	--	40	0
MAGNESIUM, ppm	MG	--	180	2
TITANIUM, ppm	TI	--	.2	2
VANADIUM, ppm	V	--	42	140
CADMIUM, ppm	CD	--	0	2
MANGANESE, ppm	MN	--	0	0

1/ The industry reference is for heat balance purposes and is taken from the Society of Naval Architects and Marine Engineers (SNAME) Technical and Research Bulletin 3 - 11, SNAME, 1972.

2/ These averages for oxygen, phosphorus, and boron are artificially high because the quantities indicated were used to represent any sample that fell below these test limits.

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INTRODUCTION

1.1 GENERAL

This is the second worldwide analysis of marine residual bunker fuel oils conducted for the U.S. Maritime Administration (MARAD). The objective of this and the first analysis was to define both from a quantitative and qualitative analysis a broad spectrum of characteristics of marine residual fuel oil, as bunkered aboard steam turbine propelled ships, from worldwide sources.

1.2 BACKGROUND

Marine bunker fuel oil, referred to as Bunker C, is a mixture of residuum remaining from refinery processing of crude oils and, in some instances, a cutter stock to reduce the viscosity of the mixture. Because refinery processes vary worldwide, Bunker C fuels are inherently different in their properties for the primary reason that world crude oil streams differ in their chemical properties and the concentration of contaminants in the residuum. The results of the first analysis conducted in 1976 (see Reference 1) as well as the results of this study are provided to ship owners and operators to allow them to more accurately assess the possible effects of Bunker C fuels on marine propulsion systems.

Both studies collected fuel oil samples as bunkered by U.S. merchant ships from ports worldwide. The first study based its analysis upon 120 samples; this study upon 150. Both studies subjected residual fuel oil samples to physical and chemical testing as presented in Table 1.1.

Both studies identify:

- a. All samples by sample number, laboratory number, port and geographical location, and bunkering date
- b. The range and depth of samples by geographic area
- c. The average sulfur, sodium, vanadium, and hydrogen content by geographical area

d. The high, low, and average values of physical and chemical properties by geographic area

e. A comparison of the "average" characteristic for all samples against the prevailing industry reference.

Tables 1.2 through 1.11 and Figures 1.1 through 1.4 present sample distribution by port within geographical area, summarized by geographical areas as well as the number of shipping companies participating, months during which samples were collected, and a geographic comparison of the 1976 and 1980 sample selection. This study provides, in addition, a statistically derived standard deviation of the test results. This statistic provides the degree to which sample test results tend to spread from the averages obtained.

TABLE 1.1
CHEMICAL AND PHYSICAL TEST METHODS USED

I. CHEMICAL TESTS

1. Reported by Percentage (%)

TEST	TEST METHOD
Carbon	Micro Elemental Analysis
Hydrogen	Micro Elemental Analysis
Nitrogen	Micro Elemental Analysis
Oxygen	Micro Elemental Analysis
Ash	ASTM Test No. D-482
Sulfur	ASTM Test No. D-129

2. Reported by parts per million (ppm) using
ASTM Test No. D-2788 except Phosphorus
ASTM Test No. D-1091

Lead	Silicon	Barium
Copper	Boron	Magnesium
Chromium	Sodium	Titanium
Aluminum	Phosphorus	Cadmium
Nickel	Zinc	Manganese

II. PHYSICAL TESTS

1. API Gravity at 60°F (°API) ASTM Test No. D-287
2. Flash Point (°F) ASTM Test No. D-83
3. Viscosity (SSU) ASTM Test No. D-445
4. Viscosity (Redwood No 1 Seconds) Conversion
from Viscosity (SSU)
5. Heating Value Conversion from API Gravity
6. Specific Weight Conversion from API Gravity

TABLE 1.2
SAMPLE DISTRIBUTION: EAST COAST, USA AND CANADA (1)

No. of Samples	World Port Index	Port
1	02180	Quebec, Canada
1	03390	Windson, Ontario, Canada
3	03700	Sarinia, Ontario, Canada
2	07350	Boston, MA, USA
1	07570	Bridgeport, CN, USA
2	07630	Brooklyn, NY, USA
4	07640	New York, NY, USA
1	08040	Deepwater, NJ, USA
1	08070	Marcus Hook, PA, USA
2	08100	Fort Mifflin, PA, USA
2	08110	Philadelphia, PA, USA
1	08115	Paulsboro, NJ, USA
4	08210	Baltimore, MD, USA
1	08280	Norfolk, VA, USA
1	08300	Newport News, VA, USA
2	08430	Moorehead City, NC, USA
3	08530	Savannah, GA, USA
1	08580	Jacksonville, FL, USA
33	18 Ports	Representing: 16 Companies

TABLE 1.3
SAMPLE DISTRIBUTION: GULF COAST, USA (2)

No. of Samples	World Port Index	Port
3	08670	Tampa, FL, USA
3	08860	New Orleans, LA, USA
1	08970	Baton Rouge, LA, USA
1	09075	Nederland, TX, USA
3	09080	Port Arthur, TX, USA
2	09150	Galveston, TX, USA
2	09170	Baytown, TX, USA
2	09240	Houston, TX, USA
3	09300	Corpus Christi, TX, USA
20	9 Ports	Representing 11 Companies

TABLE 1.4
SAMPLE DISTRIBUTION: WEST COAST, USA (3)

No. of Samples	World Port Index	Ports
2	16010	San Diego, CA, USA
1	16070	Long Beach, CA, USA
5	16080	San Pedro/Los Angeles, CA, USA
2	16300	San Francisco, CA, USA
2	16340	Oakland, CA, USA
1	16400	Oleum, CA, USA
1	16470	Benicia, CA, USA
1	16940	Portland, OR, USA
3	17700	Tacoma, WA, USA
1	17730	Seattle, WA, USA
1	18040	Anacortes, WA, USA
20	11 Ports	Representing 11 Companies

TABLE 1.5
SAMPLE DISTRIBUTION: CENTRAL AMERICA AND CARRIBEAN (4)

No. of Samples	World Port Index	Ports
1	09425	Coatzacoalcos, Mexico
7	11205	Yabucoa, Puerto Rico
2	11325	St. Croix, Virgin Islands
3	11555	Limetree Bay, Virgin Islands
6	15410	Balboa, Panama
19	5 Ports	Representing 7 Companies

TABLE 1.6
SAMPLE DISTRIBUTION: SOUTH AMERICA (5)

No. of Samples	World Port Index	Ports
2	11730	Pointe-a-Perrie, Trinidad
2	11950	Puerto LaCruz, Venezuela
1	11951	Matanzas, Venezuela
1	11960	Maricaibo, Venezuela
1	12050	Punta Cardon, Venezuela
1	12730	Recife, Brazil
1	12770	Salvador, Brazil
3	12970	Santos, Brazil
2	12980	Paranagua, Brazil
1	13060	Rio Grande, Brazil
1	13650	San Nicolas, Argentina
3	13760	Buenos Aires, Argentina
1	14500	Valparaiso, Chile
20	13 Ports	Representing 6 Companies

TABLE 1.7
SAMPLE DISTRIBUTION: NORTHERN EUROPE (6)

No. of Samples	World Port Index	Ports
1	23940	Bfjordjorden, Sweeden
1	31600	Amsterdam, Netherlands
2	31140	Rotterdam, Netherlands
1	34885	Pembroke, United Kingdom
1	35850	Rouen, France
2	37990	Lisbon, Portugal
1	38290	Cadiz, Spain
9	7 Ports	Representing 4 Companies

TABLE 1.8
SAMPLE DISTRIBUTION: MEDITERRANIAN AND AFRICA (7)

No. of Samples	World Port Index	Ports
1	36860	Donges, France
1	38775	Lavera, France
1	39130	Sarroch, Sardegna
1	39210	Cagliari, Italy
2	39470	Genova, Italy
1	45820	Dakar, Senegal
1	46770	Capetown, South Africa
6	46850	Durban, South Africa
14	8 Ports	Representing 7 Companies

TABLE 1.9
SAMPLE DISTRIBUTION: ASIA AND AUSTRALIA (8)

No. of Samples	World Port Index	Ports
3	48140	Jeddah, Saudi Arabia
2	48335	Ad Dammam, Saudi Arabia
3	49240	Colombo, Sri Lanka
5	50000	Singapore, Singapore
1	50010	Tanjang Penjori, Singapore
1	57840	Hong Kong, Hong Kong
15	6 Ports	Representing 6 Companies

TABLE 1.10
SAMPLE DISTRIBUTION SUMMARY
(by Geographic Region)

1976 SURVEY			1980 SURVEY				
Geographic Region	Quantity		Geographic Region		Quantity		
Area	Ports ^{1/}	Sp's	Code	Area	Ports	Sp's	Co's
East Coast, USA	8	31 ^{2/}	1	East Coast, USA & Canada	18	53	16
Gulf Coast, USA	1	4	2	Gulf Coast, USA	9	20	11
West Coast, USA	3	12	3	West Coast, USA	11	20	11
			4	Central America & Caribbean	5	19	7
South America	3	15	5	South America	13	20	6
Europe	2	15	6	Europe	7	9	4
Mediterranean	5	21	7	Mediterranean & Africa	8	14	7
Africa	4	9					
Asia/Australia	4	13	8	Asia/Australia	6	15	6
	30	120			75	150	28 ^{3/}

^{1/} Port distribution in the 1976 study indicate sample collection points and not necessarily the actual location of bunkering.

^{2/} Two of the samples were eliminated from the statistical results because they were not "Bunker C" fuel oil.

^{3/} Represents the total number of companies participating in the survey.

TABLE 1.11
SAMPLE COLLECTION BY MONTH WITHIN GEOGRAPHIC REGION

Month \ Region	1	2	3	4	5	6	7	8	Total
Month	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	
April	1	2	--	--	2	--	1	1	7
May	3	1	4	2	3	--	3	2	18
June	12	6	4	5	2	3	2	3	37
July	6	1	6	5	6	4	7	2	37
August	6	7	5	5	6	1	1	7	38
September	4	3	1	2	--	1	--	--	11
October	1	--	--	--	1	--	--	--	2

Geographic Region

- (1) East Coast USA and Canada
- (2) Gulf Coast USA
- (3) West Coast USA
- (4) Central America and Caribbean
- (5) South America
- (6) Northern Europe
- (7) Mediterranean and Africa
- (8) Asia and Australia

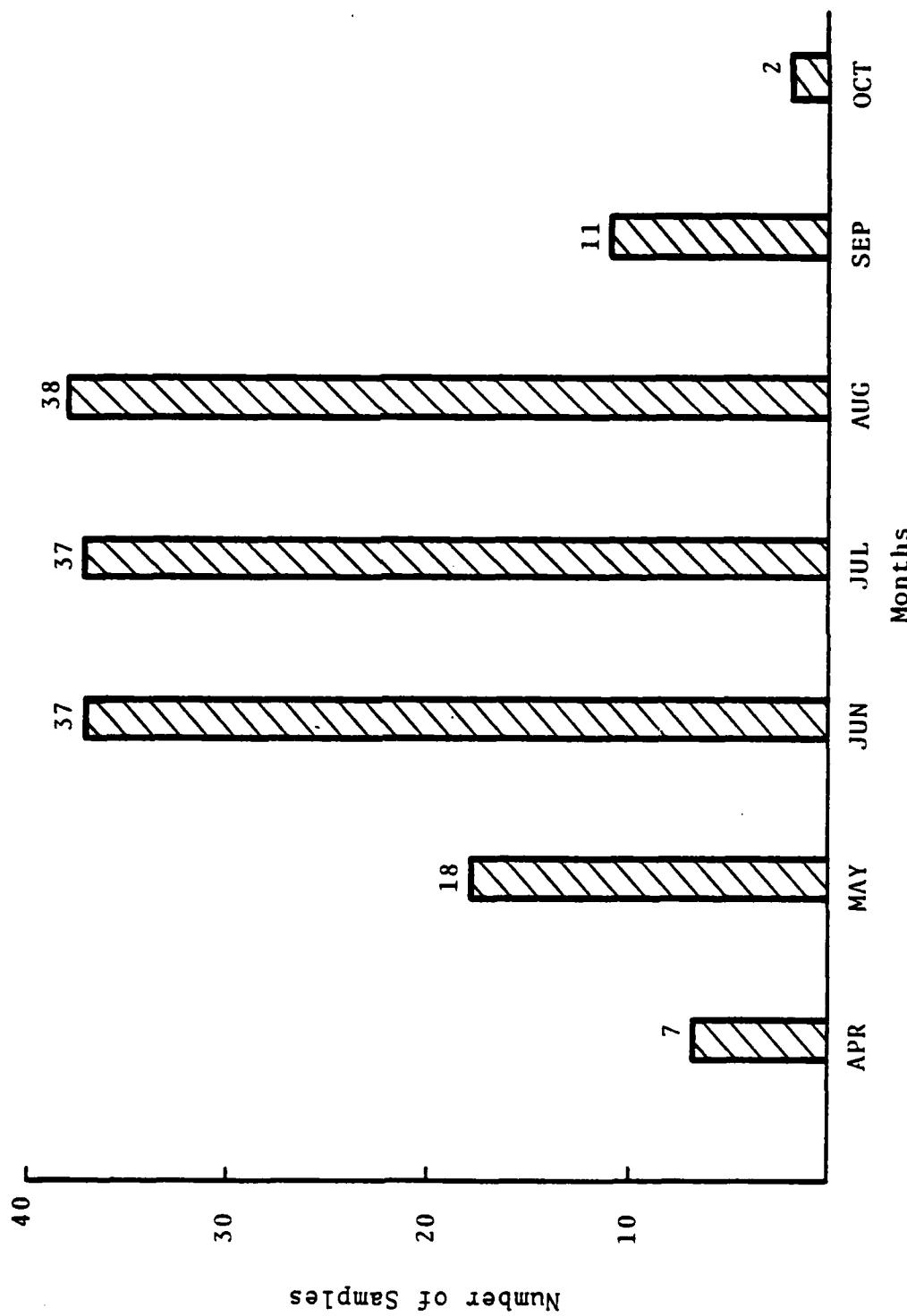


FIGURE 1.1
SAMPLE DISTRIBUTION BY MONTH

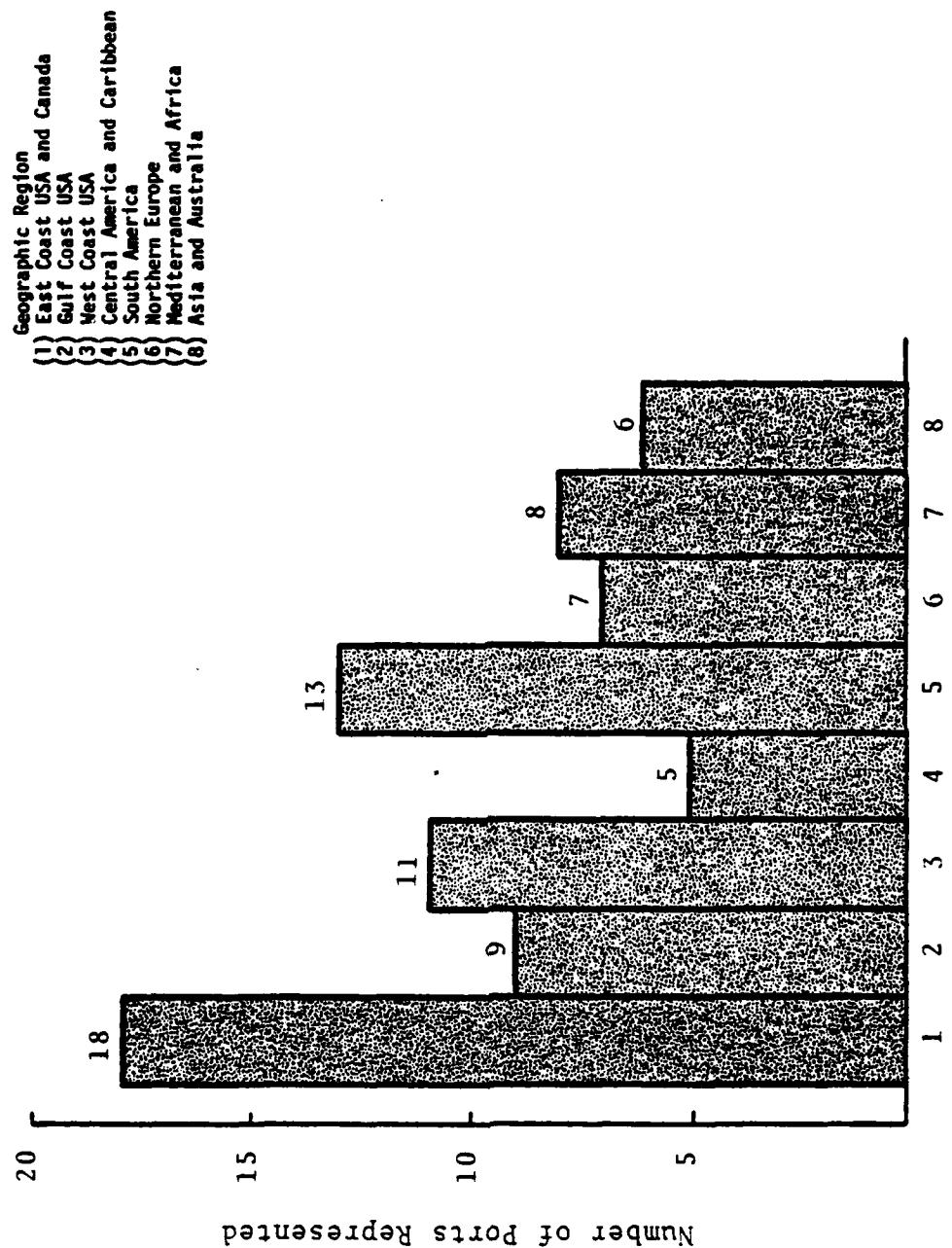


FIGURE 1.2
 PORT DISTRIBUTION BY GEOGRAPHIC REGION

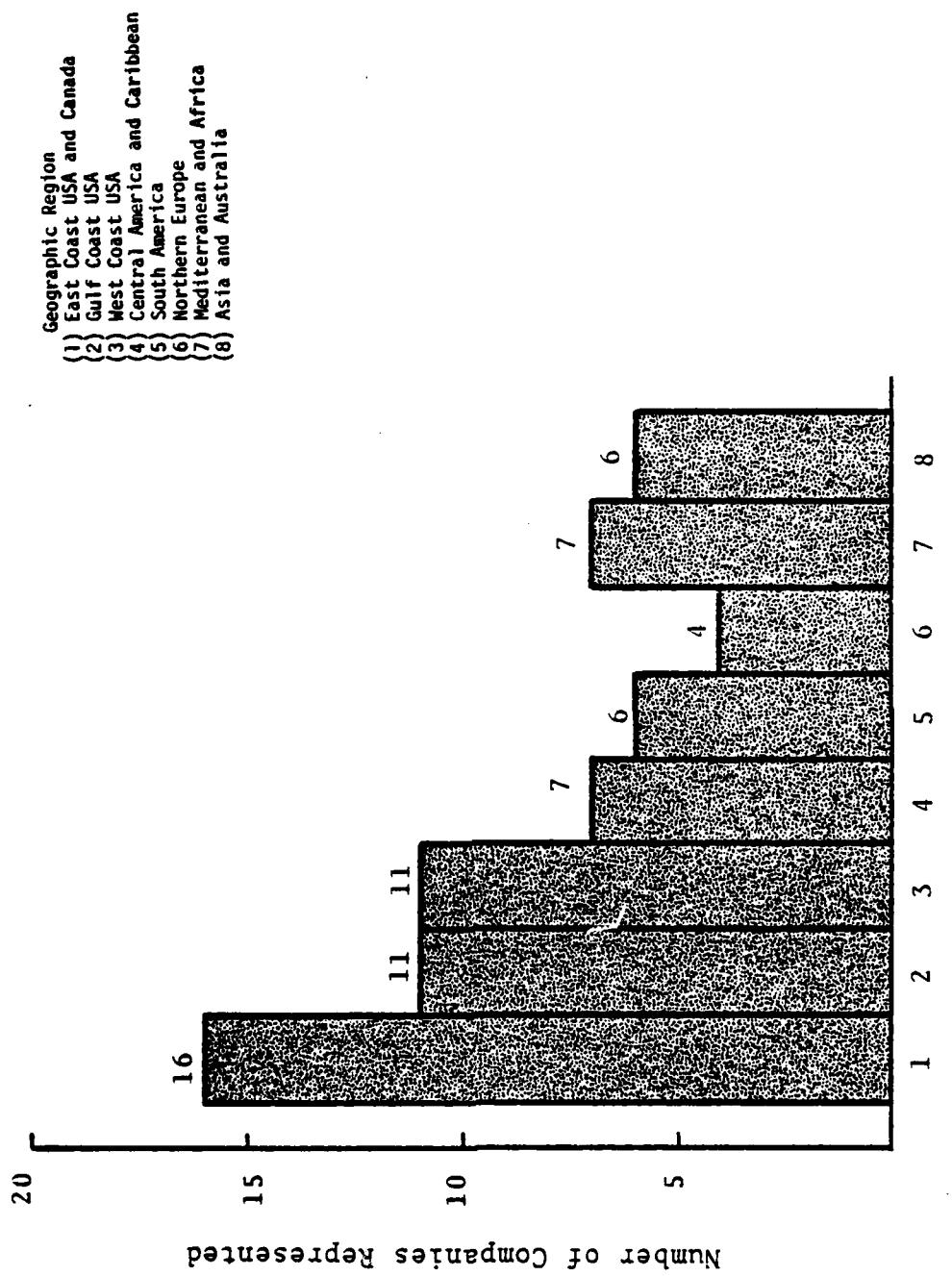


FIGURE 1.3
 COMPANY PARTICIPATION BY GEOGRAPHIC REGION

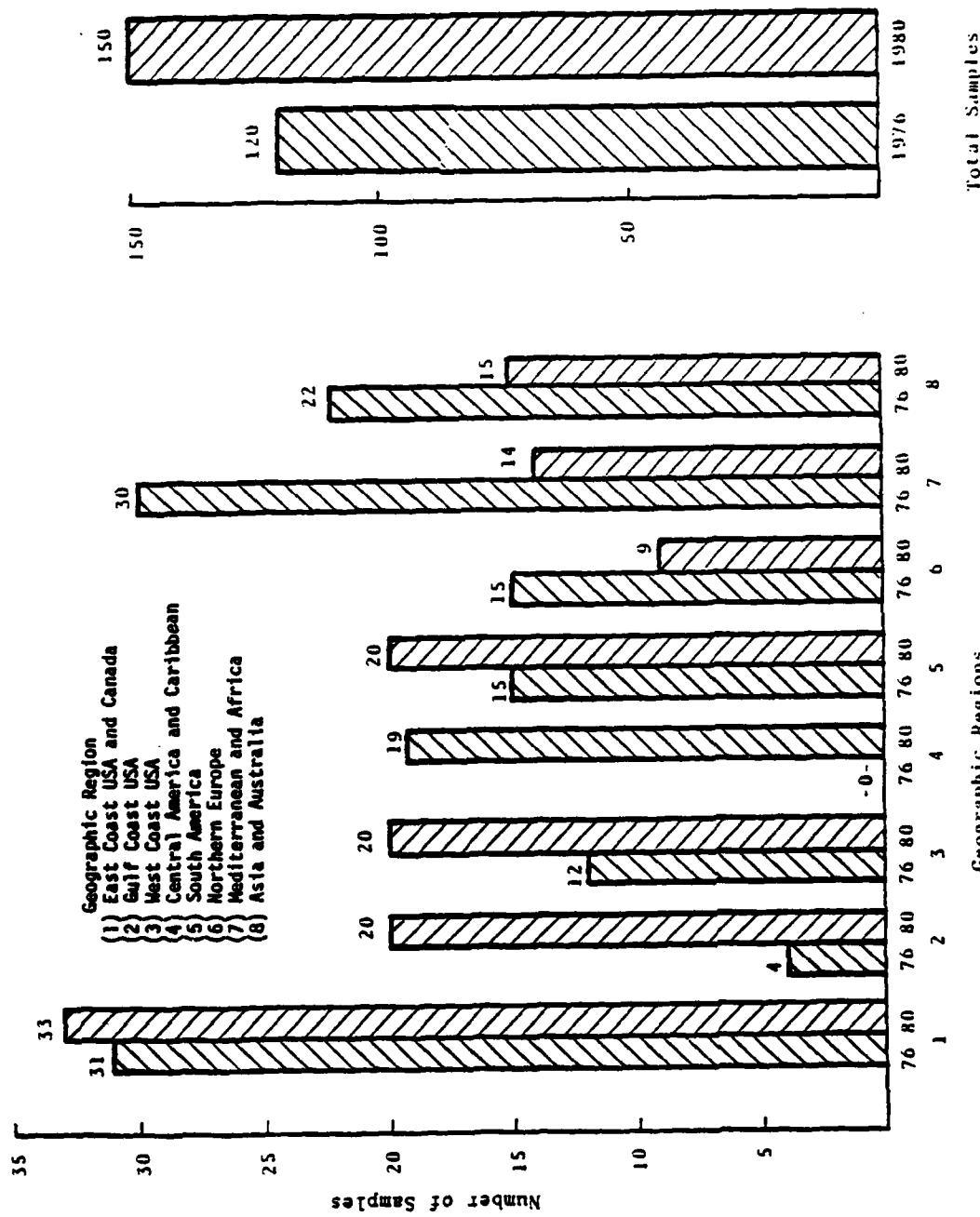


FIGURE 1.4
 COMPARISON OF 1976 SURVEY VS 1980 SURVEY

II. SURVEY RESULTS

2.1 GENERAL

This chapter presents the quantitative and qualitative results of the survey. The test results for each of the fuel samples are presented, as well as a table that allows a direct comparison between regions and the new world average by test result. Next, the new world average Bunker C fuel characteristics are compared to the previous survey and to the industry reference. For seven important test characteristics, a graphic representation by regions is presented for quick visual reference and the 95% confidence interval is established for the world average test results. The methodology to compute the 95% confidence level about the average is also presented.

2.2 SAMPLE RESULTS

The results of the physical and chemical tests, the port, the region, and the date the sample was taken are presented in Table 2.1. Three tests are limited in the minimum measurable levels detectable when using the ASTM test standards. These include oxygen at 0.5%, phosphorus at 30 ppm, and boron at 15 ppm. Hence, these values are assigned to those test results for the statistical interpretation of results. This means that the calculated average is artificially high for these test results. The ASTM D-2788 (atomic absorption spectrophotometry) method was used for analysis of trace metals and salts. This method does not provide a true measure of refinery catalytic fines that may be present in the fuel. However, in testing for silicon and aluminum, a hotter flame was used, which increased the accuracy of these test results. A standard fuel and element lamp was used to recalibrate the spectrophotometric test apparatus between the individual sample tests.

The cumulative results from the tests are presented by region in terms of the minimum, maximum, average, and one standard deviation. This result is presented in Table 2.2. The minimum and maximum provide the ranges of sample results, while the average value represents the central value of this particular survey result.

The standard deviation is helpful when computing confidence intervals. The newly computed world average fuel is compared to the 1976 survey results and to the industry reference in Table 2.3. The confidence interval develops a range into which the true average may fall with a probability of 95%. The multipliers needed to compute a 95% confidence interval are presented in Table 2.4. The standard deviation on Table 2.2 is multiplied by the "multiplier" factor for any region or the world total. The lower limit of the confidence range is the result of applying the multiplier times one standard deviation and then subtracting the number from the average. Similarly, to get the upper limit, the multiplier times one standard deviation is added to the average. This assumes a normal distribution of Bunker C within any given region and for the world average.

The results of seven of the tests are presented graphically to provide a quick visual reference by region and for the world average. These tests include three physical tests, API gravity, flash point, and viscosity (Redwood), which are commonly used by the ship's engineer to identify the fuel and to adjust fuel flow into burners, and four chemical tests, percent hydrogen and sulfur and parts per million sodium and vanadium, which relate to the corrosiveness of the fuel and to the rate of scale buildup on fuel lines and burner tips at high temperatures. The API gravity is presented in Figure 2.1, the flash point in Figure 2.2, the viscosity in Figure 2.3, the hydrogen in Figure 2.4, the sulfur in Figure 2.5, the sodium in Figure 2.6, and, finally, the vanadium in Figure 2.7. From an examination of Figures 2.1 through 2.7, the following observations can be made:

- a. The highest regional average for API gravity can be found in Asia/Australia at 16.73, followed by South America at 14.45. The lowest regional average for API gravity is found on the West Coast of the U.S. at 12.25. The newly computed world average for the API gravity is 13.53 with a 95% confidence interval whose lower limit is 13.25 and upper limit is 13.81.
- b. The highest regional average for the flash point can be found in the Central American/Caribbean region at 224, followed by Northern Europe at 216. The lowest regional average for flash point is found in Asia/Australia at 174. The newly computed world average for flash point is 196 with a 95% confidence interval whose lower limit is 192 and upper limit is 200.
- c. The highest regional average for viscosity (Redwood) can be found in South America at 4,322, followed by the West Coast of the U.S. at 4,209. The lowest regional average for viscosity is found in Asia/Australia at 1,161. The newly computed

world average for viscosity (Redwood) is 3,478 with a 95% confidence interval whose lower limit is 3,264 and upper limit is 3,692.

d. The highest regional average for hydrogen percent can be found in Asia/Australia at 11.23, followed by South America at 11.05. The lowest regional average for hydrogen percent is found in the Gulf Coast of the U.S. at 10.66. The newly computed world average for hydrogen percent is 10.86 with a 95% confidence interval whose lower limit is 10.81 and upper limit is 10.91.

e. The highest regional average for sulfur percent can be found in Northern Europe at 3.23, followed by Asia/Australia at 3.22. The lowest regional average for sulfur percent is found on the West Coast of the U.S. at 1.76. The newly computed world average for sulfur percent is 2.61 with a 95% confidence interval whose lower limit is 2.51 and upper limit is 2.71.

f. The highest regional average for sodium levels can be found in the Mediterranean/African region at 19, followed by Central America/Caribbean at 16. The lowest regional average for sodium level is found in the Gulf Coast of the U.S. at 7. The newly computed world average for sodium level is 13 with a 95% confidence interval whose lower limit is 12 and upper limit is 14.

g. The highest regional average for vanadium levels can be found on the East Coast of the U.S. and Canada at 249, followed by South America at 179. The lowest regional average for vanadium level is found in Asia/Australia at 33. The newly computed world average for vanadium levels is 141. Examination of the vanadium results indicates that vanadium is not normally distributed; hence, no confidence interval is established.

2.3 WATCH SAMPLE RESULTS

Six samples were chosen from two U.S. ports and four overseas ports. The results of laboratory tests for these samples are presented in Table 2.5. The intent of these watch samples is to provide an independent means to check the validity of the basic 150 samples. The watch sample results appear to correlate with the average from the region within plus or minus one standard deviation. Hence, the basic 150-sample data base appears sound. The three watch samples from Region Seven are all from the Mediterranean area, with two provided by AGIP Petrolia S.P.A., a refiner in Italy, and one provided by the Defense Fuel Quality Assurance Residence in Greece as received from a local refiner there.

2.4 CONCLUSIONS

The comparison presented in Table 2.3 shows an overall degradation in available bunker fuels since the previous survey was completed in 1976. The most dramatic degradation occurred in the average vanadium level, which increased from 40 ppm in 1976 to 140 ppm in this survey. As with other data presented in this report, care should be exercised in the statistical analysis of the results. For example, 30% of the fuel samples had vanadium contents of 200 ppm or higher.

TABLE 2.1
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	1	2	3	4	5	6	7	8
SAMPLE NUMBER CONTROL	LAB NO.	120	10	54	55	171	159	163	75
BUNKERING PORT	API	02180	03390	03700	33700	03700	07350	07350	07570
GEOGRAPHICAL REGION	I CODE	1	1	1	1	1	1	1	1
DATE BUNKERED	MO/DAY/YR	6/11/80	7/11/80	8/2/80	3/13/80	9/20/80	9/1/80	9/22/80	8/27/80
CARBON %	C	85.69	37.38	36.31	86.40	87.30	85.91	86.25	86.53
HYDROGEN %	H	11.46	10.91	10.34	10.23	10.79	10.63	10.38	10.38
NITROGEN %	N	0.33	0.42	0.33	0.22	0.32	0.50	0.48	0.35
OXYGEN % (< 0.5%)	O	0.5	0.5	0.60	0.5	0.55	0.55	0.63	0.67
SULFUR %	S	2.29	1.73	1.98	2.19	1.16	2.20	2.25	1.51
ASH %	ASH	0.07	0.04	0.06	0.08	0.04	0.20	0.14	0.05
API GRAVITY @ 60°F	GRAV	14.9(15.6)	12.7(12.3)	11.8(13.5)	12.2(12.9)	12.1	13.5(13.6)	13.4(13.6)	12.4(15.0)
PM FLASH POINT (0°F)	FLASH	262	214(196)	214(169)	146(154)	208(150)	162(180)	176(180)	186(200)
VISCOSEITY (SSU @ 100°F)	VISSSU	5583	3573	4887	5406	4141	6253	5711	4776
VISCOSEITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	4894	3132	4284	4739	3630	5482	5006	4187
HEATING VALUE BTU/LB	HTVAL	18219	18520	18570	18420	18480	18290	18330	18180
SPECIFIC WEIGHT LB/GAL	SPECWT	8.07	8.19	8.24	8.22	8.21	8.14	8.15	8.19
PHOSPHORUS, ppm (< 30 ppm)	P	48	32	30	50	30	30	30	30
IRON, ppm	FE	7	19	17	15	12	5	5	8
LEAD, ppm	PB	1	0	2	2	1	4	4	3
COPPER, ppm	CU	0	0	0	0	1	1	2	1
CHROMIUM, ppm	CR	0	0	1	1	0	0	1	0
ALUMINUM, ppm	AL	12	10	12	10	15	16	15	14
NICKEL, ppm	NI	38	32	40	36	16	76	78	28
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	2	2	3	3	0	4	3	3
SILICON, ppm	SI	11	18	18	23	15	15	10	16
BORON, ppm (<15 ppm)	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	14	17	7	8	8	14	17	12
ZINC, ppm	ZN	0	8	9	0	1	4	1	1
CALCIUM, ppm	CA	7	9	8	5	3	9	8	4
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	7	3	2	1	1	4	4	2
TITANIUM, ppm	TI	1	0	0	0	1	6	5	3
VANADIUM, ppm	V	220	32	54	54	27	590	600	135
CADMIUM, ppm	CD	0	5	4	4	0	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

1/ This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

2/ The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	9	10	11	12	13	14	15	16
SAMPLE NUMBER CONTROL	LAB NO.	123	229	23	34	39	196	28	20
BUNKERING PORT	WPI	07630	07630	07640	07640	07640	07640	08040	08070
GEOGRAPHICAL REGION	I CODE	1	1	1	1	1	1	1	1
DATE BUNKERED	MO/DAY/YR	5/31/80	10/9/80	6/7/80	5/10/80	6/13/80	3/1/80	7/10/80	5/21/80
CARBON %	C	35.75	35.24	35.91	35.42	35.76	36.44	35.46	37.39
HYDROGEN %	H	10.94	10.20	11.18	11.28	11.18	10.54	11.08	11.01
NITROGEN %	N	0.37	0.44	0.48	0.40	0.29	0.22	0.45	0.24
OXYGEN % (< 0.5%) ^{1/}	O	0.59	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	2.26	2.30	2.24	2.29	2.87	2.56	2.58	1.02
ASH %	ASH	0.11	0.02	0.07	0.10	0.06	0.07	0.10	0.02
API GRAVITY @ 60°F ^{2/}	GRAV	15.7(15.1)	9.9 (10.2)	15.9	15.5(15.1)	12.5(12.5)	12.1(12.7)	16.0(16.2)	12.7
PM FLASH POINT (0°F) ^{2/}	FLASH	152(150)	168(148)	170	168(150)	214(194)	204(200)	194(160)	236
VISCOSITY (SSU @ 100°F)	VISSU	3960	2983	3507	4103	4742	2992	4425	4997
VISCOSITY REDWOOD W. 1 SEC @ 100°F	VISRWD	3471	2615	3074	3597	4157	2623	3879	4381
HEATING VALUE BTU/LB	HTVAL	18490	18320	18450	18390	18150	18390	18490	18080
SPECIFIC WEIGHT LB/GAL	SPECWT	8.00	8.34	8.01	8.03	8.20	8.20	8.00	8.19
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	105	185	95	30	86	84
IRON, ppm	FE	7	6	6	6	7	4	4	17
LEAD, ppm	PB	5	2	2	3	2	1	2	3
COPPER, ppm	CU	1	0	0	0	0	0	2	2
CHROMIUM, ppm	CR	0	0	1	1	1	1	1	1
ALUMINUM, ppm	AL	18	14	9	13	13	10	7	9
NICKEL, ppm	NI	48	30	55	58	25	21	54	20
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	6	3	4	1	2	2	1	1
SILICON, ppm	SI	18	6	24	26	24	14	25	25
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	17	12	15	10	12	8	4	11
ZINC, ppm	ZN	0	1	0	0	4	2	2	10
CALCIUM, ppm	CA	2	5	5	2	3	1	2	18
SARIUM, ppm	SA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	4	1	3	3	3	1	1	3
TITANIUM, ppm	TI	5	2	8	9	0	2	6	5
VANADIUM, ppm	V	285	115	390	425	120	47	460	36
CAOMIUM, ppm	CO	0	0	4	2	5	0	3	6
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	17	18	19	20	21	22	23	24
SAMPLE NUMBER CONTROL	LAB NO.	260	261	29	95	89	33	44	38
BUNKERING PORT	WPI	08100	08100	38110	08110	08115	08210	08210	08210
GEOGRAPHICAL REGION	I CODE	1	1	1	1	1	1	1	1
DATE BUNKERED	MO/DAY/YR	6/16/80	7/15/80	5/19/80	5/21/80	7/9/80	5/3/80	5/28/80	7/20/80
CARBON %	C	34.20	35.79	36.13	35.54	35.10	35.62	35.30	35.37
HYDROGEN %	H	10.88	10.30	10.10	11.25	10.58	10.76	10.96	10.31
NITROGEN %	N	0.23	0.25	0.24	0.43	0.36	0.29	0.56	0.26
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.65	0.55	0.5	0.5	0.5
SULFUR %	S	4.30	2.75	3.09	2.01	3.15	3.98	2.20	2.56
ASH %	ASH	0.03	0.07	0.07	0.11	0.06	0.06	0.09	0.12
API GRAVITY @ 60°F ^{2/}	GRAV	16.3	17.1	12.9(13.3)	15.9	13.1(13.9)	11.7(13.8)	13.2(13.9)	11.7(11.9)
PM FLASH POINT (0°F) ^{2/}	FLASH	172	206	192(200)	134	152(210)	184(180)	168(148)	256(200)
VISCOOSITY (SSU @ 100°F)	VISSSU	1431	1223	869	3108	2487	4046	5853	4528
VISCOOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	1254	1072	762	2725	2180	3547	5131	3969
HEATING VALUE BTU/LB	HTVAL	18620	18920	18660	18850	18400	17950	19380	18001
SPECIFIC WEIGHT LB/GAL	SPECWT	7.97	7.93	8.18	8.30	8.15	8.25	8.16	8.25
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	90	30	30	50	84	30
IRON, ppm	FE	1	4	4	4	5	21	2	15
LEAD, ppm	PB	1	2	1	3	3	12	3	6
COPPER, ppm	CU	0	0	0	1	1	0	1	1
CHROMIUM, ppm	CR	0	0	1	0	0	1	1	1
ALUMINUM, ppm	AL	14	16	10	16	15	12	14	11
NICKEL, ppm	NI	14	18	21	55	47	27	81	32
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	1	1	1	6	4	0	6	4
SILICON, ppm	SI	3	5	26	17	19	25	15	16
BORON, ppm <15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	5	9	0	9	9	18	9	15
ZINC, ppm	ZN	1	1	0	0	1	7	6	0
CALCIUM, ppm	CA	0	1	1	2	2	17	8	4
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	0	1	1	3	2	5	3	4
TITANIUM, ppm	TI	0	0	6	5	4	4	0	1
VANADIUM, ppm	V	32	54	135	400	230	117	470	120
CADMIUM, ppm	CD	0	0	6	0	0	5	4	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	25	26	27	28	29	30	31	32
SAMPLE NUMBER CONTROL	LAB NO.	117	72	153	67	178	36	46	113
BUNKERING PORT	WPI	08210	08280	08300	08430	08430	08530	08530	08530
GEOGRAPHICAL REGION	I CODE	1	1	1	1	1	1	1	1
DATE BUNKERED	MO/DAY/YR	6/9/80	7/13/80	6/24/80	3/19/80	9/30/80	4/25/80	7/9/80	3/10/80
CARBON %	C	85.93	85.72	85.48	86.26	85.90	86.13	86.46	86.50
HYDROGEN %	H	10.20	11.14	11.51	10.41	11.06	11.08	11.17	11.02
NITROGEN %	N	0.26	0.52	0.40	0.49	0.41	0.28	0.50	0.36
OXYGEN % (< 0.5%) ^{1/}	O	0.52	0.57	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	3.01	2.03	2.14	2.08	2.13	2.44	2.16	1.56
ASH %	ASH	0.08	0.12	0.15	0.19	0.08	0.05	0.10	0.07
API GRAVITY @ 50°F ^{2/}	GRAV	11.1	13.3(15.4)	16.1	12.9(12.9)	14.0(12.9)	13.5(14.4)	13.5(13.4)	15.2(14.9)
PM FLASH POINT (0°F) ^{2/}	FLASH	180	166(167)	152	192(172)	195(172)	194(179)	160(190)	210(190)
VISCOSITY (SSU @ 100°F)	VISSU	4424	6012	4678	7655	3562	6538	6605	3255
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	3878	5270	4101	6711	3123	5731	5790	2353
HEATING VALUE BTU/LB	HTVAL	18100	18530	18320	18070	18290	18020	18100	18643
SPECIFIC WEIGHT LB/GAL	SPECWT	8.27	8.13	8.00	8.18	8.10	8.14	8.14	8.35
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	38	34	48	30	30	30	30
IRON, ppm	FE	21	7	2	3	2	5	3	14
LEAD, ppm	PB	13	3	2	2	1	1	3	1
COPPER, ppm	CU	1	1	1	1	0	1	1	0
CHROMIUM, ppm	CR	0	1	0	1	0	1	1	0
ALUMINUM, ppm	AL	23	10	12	14	9	12	13	10
NICKEL, ppm	NI	23	77	58	66	29	37	78	57
SILVER, ppm	AG	0	1	0	0	0	0	0	0
TIN, ppm	SN	3	7	0	6	2	4	7	5
SILICON, ppm	SI	18	18	7	22	6	18	13	9
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	23	35	10	12	5	8	7	9
ZINC, ppm	ZN	5	0	1	0	1	0	6	0
CALCIUM, ppm	CA	10	4	1	11	2	2	7	0
SARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	6	4	0	3	1	1	3	0
TITANIUM, ppm	TI	7	3	1	10	3	0	0	1
VANADIUM, ppm	V	85	500	400	500	320	190	470	160
CADMIUM, ppm	CD	0	0	0	3	0	5	5	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	33	34	35	36	37	38	39	40
SAMPLE NUMBER CONTROL	LAB NO.	57	174	223	224	64	146	200	141
BUNKERING PORT	WPI	08580	08670	08670	08670	08860	08860	08860	08970
GEOGRAPHICAL REGION	I CODE	1	2	2	2	2	2	2	2
DATE BUNKERED	MO/DAY/YR	5/23/80	9/8/80	5/15/80	8/24/80	5/25/80	9/5/80	7/15/80	3/27/80
CARBON %	C	85.94	35.31	36.24	36.42	36.30	35.38	36.28	35.44
HYDROGEN %	H	10.83	11.18	10.45	10.24	10.82	10.30	10.34	10.78
NITROGEN %	N	0.38	0.05	0.36	0.29	0.25	0.19	0.28	0.26
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.96	0.56	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	2.17	2.31	1.71	2.44	2.60	3.65	2.69	3.19
ASH %	ASH	0.11	0.08	0.02	0.01	3.11	0.06	0.03	0.04
API GRAVITY @ 50°F ^{2/}	GRAV	13.5(13.5)	15.0(15.2)	10.0	10.9(11.6)	12.2	11.1(10.6)	10.3	12.1(12.4)
PM FLASH POINT (0°F) ^{2/}	FLASH	160(200)	160(200)	198	174	210	208(200+)	184	184(215)
VISCOSITY (SSU @ 100°F)	VISSSU	5920	2413	3000	3002	4127	3520	3057	5419
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	5190	2115	2630	2532	3618	3086	2580	4750
HEATING VALUE BTU/LB	HTVAL	18020	18480	18670	18590	18230	18030	18260	17850
SPECIFIC WEIGHT LB/GAL	SPECWT	8.14	3.05	8.35	8.27	8.22	8.28	8.31	8.22
PHOSPHORUS. ppm (< 30 ppm) ^{1/}	P	30	30	30	30	30	50	30	30
IRON. ppm	FE	5	4	6	8	12	5	5	7
LEAD. ppm	PB	2	1	1	2	1	1	1	1
COPPER. ppm	CU	1	1	0	0	0	0	0	1
CHROMIUM. ppm	CR	0	0	0	0	1	0	1	0
ALUMINUM. ppm	AL	14	12	12	13	8	15	12	15
NICKEL. ppm	NI	81	45	20	12	17	14	15	29
SILVER. ppm	AG	0	0	0	0	0	0	0	0
TIN. ppm	SN	6	3	1	1	2	2	0	3
SILICON. ppm	SI	13	6	16	7	20	7	15	10
BORON. ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM. ppm	NA	11	21	7	9	8	1	1	8
ZINC. ppm	ZN	7	2	0	2	0	1	1	1
CALCIUM. ppm	CA	7	3	1	2	3	0	1	1
SARIUM. ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM. ppm	MG	2	3	0	1	1	0	1	2
TITANIUM. ppm	TI	0	3	1	1	3	1	0	3
VANADIUM. ppm	V	460	250	58	37	48	55	36	153
CADMUM. ppm	CD	5	0	0	0	5	0	0	0
MANGANESE. ppm	MN	0	0	0	0	0	0	0	0

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^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	41	42	43	44	45	46	47	48
SAMPLE NUMBER CONTROL	LAB NO.	118	1	5	5	71	147	59	142
BUNKERING PORT	API	39080	39080	39080	39080	39150	39150	39170	39170
GEOGRAPHICAL REGION	I CODE	2	2	2	2	2	2	2	2
DATE BUNKERED	MO/DAY/YR	3/6/80	6/7/80	6/9/80	6/12/80	3/23/80	3/8/80	8/17/80	8/23/80
CARBON %	C	86.53	36.47	35.90	86.20	35.50	36.11	36.79	36.14
HYDROGEN %	H	10.40	10.91	10.57	10.99	10.64	10.50	10.33	10.73
NITROGEN %	N	0.31	0.20	0.11	0.25	0.29	0.32	0.26	0.30
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	2.27	2.88	2.59	2.76	2.39	2.95	2.48	2.38
ASH %	ASH	0.06	0.07	0.04	0.04	0.10	0.10	0.19	0.06
API GRAVITY @ 60°F ^{2/}	GRAV	10.9	12.2(12.5)	12.3(13.3)	13.0(13.3)	11.5(12.0)	11.4(12.1)	11.1(11.4)	12.0(11.8)
PM FLASH POINT (0°F) ^{2/}	FLASH	216	258(196)	230(190)	244(190)	204(225)	160(162)	173(182)	210(178)
VISCOSITY (SSU @ 100°F)	VISSSU	4516	4933	5079	3412	1473	3080	4186	4553
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	3959	4324	4452	2991	3926	2700	3670	3991
HEATING VALUE BTU/LB	HTVAL	18100	18440	18590	18530	18230	18130	18200	17920
SPECIFIC WEIGHT LB/GAL	SPECWT	8.28	8.22	8.21	8.17	8.25	8.25	8.28	8.23
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	175	180	310	30	30	35	30
IRON, ppm	FE	12	14	13	14	14	14	11	10
LEAD, ppm	PB	3	1	1	1	1	3	1	2
COPPER, ppm	CU	1	0	0	0	0	1	0	1
CHROMIUM, ppm	CR	0	1	1	1	0	1	1	0
ALUMINUM, ppm	AL	18	9	8	8	10	12	12	12
NICKEL, ppm	NI	27	26	27	22	24	49	29	20
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	3	0	0	0	5	3	4	3
SILICON, ppm	SI	12	30	30	30	16	7	30	23
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	6	7	8	5	12	7	6	7
ZINC, ppm	ZN	0	0	0	0	4	1	0	1
CALCIUM, ppm	CA	1	18	14	9	0	1	3	2
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	1	3	3	2	1	1	1	1
TITANIUM, ppm	TI	11	0	0	0	1	3	4	1
VANADIUM, ppm	V	79	98	90	75	62	270	80	74
CAOMIUM, ppm	CO	0	10	10	10	0	0	5	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	49	50	51	52	53	54	55	56
SAMPLE NUMBER CONTROL	LAB NO.	59	259	62	19	66	164	165	155
BUNKERING PORT	WPI	09240	09240	09300	09300	09300	16010	16010	16070
GEOGRAPHICAL REGION	I CODE	2	2	2	2	2	3	3	3
DATE BUNKERED	MO/DAY/YR	4/27/80	5/17/80	3/8/80	5/21/80	3/16/80	8/9/80	8/10/80	5/12/80
CARBON %	C	36.13	35.67	35.56	36.44	36.15	35.63	35.31	35.72
HYDROGEN %	H	10.52	10.11	10.78	10.63	10.02	10.85	10.78	11.11
NITROGEN %	N	0.28	0.35	0.28	0.26	0.39	0.52	0.52	0.74
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.70	0.72	0.88
SULFUR %	S	2.39	3.40	2.21	2.97	2.93	2.10	2.19	1.28
ASH %	ASH	0.09	0.34	0.09	0.04	0.06	0.08	0.09	0.08
API GRAVITY @ 60°F ^{2/}	GRAV	11.9	10.1(10.7)	12.4(12.6)	12.3	10.9(13.6)	12.6(13.0)	12.5(13.3)	15.9(14.3)
PM FLASH POINT (0°F) ^{2/}	FLASH	156	216(200)	170(140)	212	164(166)	212(196)	212(196)	154(168)
VISCOSITY (SSU @ 100°F)	VISSU	3839	3979	2560	1511	11130	4234	4294	1746
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	3365	3488	2240	1325	9757	3712	3764	1531
HEATING VALUE BTU/LB	HTVAL	17980	19050	18790	17880	18350	18180	18640	18540
SPECIFIC WEIGHT LB/GAL	SPECWT	8.23	8.32	8.21	8.21	8.29	8.19	8.17	8.00
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	35	30	30	150	33	30	30	30
IRON, ppm	FE	14	10	1	14	8	35	25	58
LEAD, ppm	PB	2	1	1	0	0	24	29	18
COPPER, ppm	CU	0	0	1	0	0	1	2	1
CHROMIUM, ppm	CR	1	0	0	1	1	1	0	0
ALUMINUM, ppm	AL	10	15	15	8	10	13	11	13
NICKEL, ppm	NI	21	18	51	37	51	79	80	80
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	3	1	2	1	3	1	0	0
SILICON, ppm	SI	24	3	10	30	20	7	6	12
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	8	5	13	8	7	15	10	15
ZINC, ppm	ZN	0	2	1	0	0	15	5	9
CALCIUM, ppm	CA	21	0	1	6	0	17	10	18
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	3	0	1	3	1	3	1	3
TITANIUM, ppm	TI	6	0	2	3	5	2	2	6
VANADIUM, ppm	V	60	50	345	170	170	127	123	68
CADMIUM, ppm	CD	5	0	0	3	3	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	57	58	59	60	61	62	63	64
SAMPLE NUMBER CONTROL	LAB NO.	7	8	11	12	264	14	21	52
BUNKERING PORT	WPI	16080	16080	16080	16080	16080	16080	16300	16300
GEOPGRAPHICAL REGION	I CODE	3	3	3	3	3	3	3	3
DATE BUNKERED	MO/DAY/YR	7/3/80	7/13/80	6/21/80	7/14/80	6/23/80	5/27/80	5/24/80	6/24/80
CARBON %	C	36.90	37.46	36.89	35.90	36.27	36.51	36.39	35.85
HYDROGEN %	H	10.91	10.78	10.28	11.01	10.94	10.92	10.38	10.28
NITROGEN %	N	0.30	0.67	0.69	0.79	0.72	0.39	0.44	0.56
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.76	0.52	0.80	0.5	1.20
SULFUR %	S	1.59	1.44	1.63	1.32	1.10	1.36	1.68	1.52
ASH %	ASH	0.03	0.05	0.03	0.02	0.06	0.02	0.01	0.05
API GRAVITY @ 60°F ^{2/}	GRAV	3.7(8.8)	12.9(12.4)	3.8(9.0)	12.7(13.0)	12.7(12.4)	14.0(13.8)	15.3	12.8(13.5)
FLASH POINT (0°F) ^{2/}	FLASH	190(184)	204(230)	200(192)	176(200)	176(198)	220(220)	208	200(164)
VISCOOSITY (SSU @ 100°F)	VISSSU	6037	4310	5495	5975	4400	5500	4197	5032
VISCOOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	5292	3778	4817	5238	3857	4810	3679	4411
HEATING VALUE BTU/LB	HTVAL	18200	18460	18020	18110	18260	18300	18050	18130
SPECIFIC WEIGHT LB/GAL	SPECWT	8.35	3.18	8.42	8.19	8.17	8.12	8.04	8.18
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	36	33	91	30	30	30	36	35
IRON, ppm	FE	25	26	28	64	25	26	4	27
LEAD, ppm	PG	2	0	2	4	1	2	0	1
COPPER, ppm	CU	0	0	1	1	0	0	0	0
CHROMIUM, ppm	CR	1	0	1	0	0	0	1	0
ALUMINUM, ppm	AL	7	9	11	12	20	13	8	10
NICKEL, ppm	NI	65	68	70	88	46	62	38	73
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	6	3	3	4	3	1	2	3
SILICON, ppm	SI	35	13	28	15	8	7	20	7
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	6	6	3	7	12	11	0	13
ZINC, ppm	ZN	0	6	0	4	1	1	0	25
CALCIUM, ppm	CA	0	5	2	3	2	8	1	24
SARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	1	1	0	2	1	2	0	3
TITANIUM, ppm	TI	0	0	8	6	4	1	10	0
VANADIUM, ppm	V	89	78	130	60	32	61	87	82
CADMIUM, ppm	CD	13	5	8	0	0	0	4	6
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	65	66	67	68	69	70	71	72
SAMPLE NUMBER CONTROL	LAB NO.	139	263	74	176	77	1	2	3
BUNKERING PORT	WPI	16340	16340	16400	16470	16940	17700	17700	17700
GEOGRAPHICAL REGION	I CODE	3	3	3	3	3	3	3	3
DATE BUNKERED	MO/DAY/YR	9/30/80	7/5/80	3/20/80	9/7/80	3/4/80	5/2/80	3/27/80	6/4/80
CARBON %	C	86.71	86.53	84.73	86.31	87.11	85.48	86.31	85.81
HYDROGEN %	H	10.91	10.59	10.84	10.58	10.28	11.22	11.12	11.13
NITROGEN %	N	0.65	0.69	0.82	0.73	0.62	0.66	0.69	0.63
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.55	0.5	0.59	0.5	0.5	0.5	0.5
SULFUR %	S	1.62	1.63	2.30	1.70	1.38	2.40	1.39	2.22
ASH %	ASH	0.36	0.10	0.24	0.08	0.17	0.35	0.04	0.01
API GRAVITY @ 60°F ^{2/}	GRAV	11.8(12.4)	12.1(11.0)	12.9	11.2(11.1)	12.4(9.5)	14.0(14.0)	14.2(14.3)	13.7(14.1)
PM FLASH POINT (0°F) ^{2/}	FLASH	202(180)	190(170)	178	195(165)	192(180)	194(170)	212(210)	188(176)
VISCOSITY (SSU @ 100°F)	VISSSU	5327	5081	5180	4873	2870	4670	3949	5912
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	4670	4454	4541	4272	2516	4094	3462	5183
HEATING VALUE BTU/LB	HTVAL	18100	18010	18580	18480	18720	18490	18570	18410
SPECIFIC WEIGHT LB/GAL	SPECWT	8.24	8.21	8.18	8.26	8.21	8.12	8.10	8.13
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	110	30	77	134	47	254
IRON, ppm	FE	39	18	23	38	38	22	26	18
LEAD, ppm	PB	2	1	1	2	1	1	1	1
COPPER, ppm	CU	1	0	0	1	0	0	0	0
CHROMIUM, ppm	CR	0	0	0	0	0	1	1	1
ALUMINUM, ppm	AL	19	16	8	16	3	9	3	10
NICKEL, ppm	NI	85	44	103	90	92	90	72	68
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	3	4	3	1	5	3	0	0
SILICON, ppm	SI	11	4	15	12	15	24	26	24
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	31	25	15	43	40	10	7	9
ZINC, ppm	ZN	3	3	0	1	1	0	0	0
CALCIUM, ppm	CA	17	12	11	32	33	18	25	28
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	4	2	1	5	6	2	3	7
TITANIUM, ppm	TI	2	3	1	2	4	0	0	0
VANADIUM, ppm	V	114	59	150	135	108	120	75	106
CAOUMIUM, ppm	CD	0	0	0	0	0	7	8	7
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	73	74	75	76	77	78	79	80
SAMPLE NUMBER CONTROL	LAB NO.	49	247	15	16	17	24	25	144
BUNKERING PORT	WPI	17730	09425	11205	11205	11205	11205	11205	11205
GEOPGRAPHICAL REGION	I CODE	3	4	4	4	4	4	4	4
DATE BUNKERED	MO/DAY/YR	7/11/80	8/15/80	7/12/80	7/12/80	5/28/80	5/15/80	5/29/80	5/26/80
CARBON %	C	35.26	34.59	36.27	36.57	35.98	36.46	36.45	36.35
HYDROGEN %	H	10.30	10.44	10.88	11.64	10.88	11.03	10.36	11.22
NITROGEN %	N	0.73	0.33	0.41	0.43	0.39	0.42	0.46	0.26
OXYGEN % (< 0.5%) ^{1/}	O	1.31	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	1.46	3.82	1.98	1.96	2.10	2.57	2.36	2.38
ASH %	ASH	0.19	0.05	0.01	0.04	0.04	0.03	0.03	0.04
API GRAVITY @ 60°F ^{2/}	GRAV	11.1(11.7)	12.2	14.6	14.9	12.4	12.8	13.0	15.6
DM FLASH POINT (0°F) ^{2/}	FLASH	164(180)	144	254	258	250	266	262	188
VISCOOSITY (SSU @ 100°F)	VISSSU	5798	3863	4812	4716	5545	9538	7290	926
VISCOOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	5083	3386	4218	4134	4861	3361	5382	312
HEATING VALUE BTU/LB	HTVAL	17490	18680	18230	18370	18140	18320	17950	18110
SPECIFIC WEIGHT LB/GAL	SPECWT	8.28	8.2	8.07	8.07	8.19	8.18	8.17	8.03
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	30	64	30	50	71	33
IRON, ppm	FE	36	2	9	10	6	6	8	6
LEAD, ppm	PB	1	2	0	1	0	0	0	1
COPPER, ppm	CU	1	0	1	0	1	0	0	0
CHROMIUM, ppm	CR	1	0	0	1	0	1	1	0
ALUMINUM, ppm	AL	11	14	13	7	14	6	7	13
NICKEL, ppm	NI	100	34	35	41	31	31	39	25
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	3	3	3	0	2	2	0	4
SILICON, ppm	SI	11	5	7	20	7	23	24	4
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	10	6	13	9	9	7	3	7
ZINC, ppm	ZN	39	1	0	3	1	0	0	1
CALCIUM, ppm	CA	57	0	2	3	2	0	0	0
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	8	0	3	2	2	0	1	1
TITANIUM, ppm	TI	0	1	7	5	5	5	7	2
VANADIUM, ppm	V	105	199	103	128	107	125	147	108
CAIDIUM, ppm	CD	7	0	0	5	0	5	6	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	81	92	83	84	85	86	87	98
SAMPLE NUMBER CONTROL	LAB NO.	145	11	42	108	112	127	91	85
BUNKERING PORT	WPI	11205	11325	11325	11335	11335	11335	15410	15410
GEOGRAPHICAL REGION	I CODE	4	4	4	4	4	4	4	4
DATE BUNKERED	MO/DAY/YR	8/1/80	6/16/80	6/27/80	8/26/80	7/24/80	7/26/80	8/11/80	8/11/80
CARBON %	C	86.50	86.58	86.69	86.01	86.09	85.82	85.00	86.06
HYDROGEN %	H	10.90	11.36	11.41	10.88	10.64	10.63	11.09	10.48
NITROGEN %	N	0.37	0.34	0.30	0.33	0.23	0.27	0.25	0.28
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.51	0.5	0.51	0.5	0.5
SULFUR %	S	1.98	2.04	2.25	2.27	2.77	2.75	3.43	2.46
ASH %	ASH	0.04	0.04	0.04	0.01	0.10	0.07	0.08	0.07
API GRAVITY @ 60°F ^{2/}	GRAV	12.5	13.4(13.8)	14.9(15.2)	12.0(12.7)	12.2(12.9)	12.2(12.4)	14.1(14.3)	13.4(15.0)
PM FLASH POINT (0°F) ^{2/}	FLASH	186	224 (180)	254 (180)	236 (180)	244 (180)	236 (180)	238 (217)	245 (185)
VISCOSITY (SSU @ 100°F)	VISSSU	6517	3915	3469	3858	4595	4456	4514	4304
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	5713	3432	3041	5382	4028	3906	3957	3773
HEATING VALUE BTU/LB	HTVAL	18060	18520	18520	18750	18510	18370	18020	18183
SPECIFIC WEIGHT LB/GAL	SPECWT	8.20	8.15	8.07	8.21	8.20	8.20	8.11	8.15
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	37	50	30	30	30	30	30
IRON, ppm	FE	8	6	7	5	16	12	3	6
LEAD, ppm	PB	1	0	0	2	2	3	1	2
COPPER, ppm	CU	0	0	0	1	1	1	0	1
CHROMIUM, ppm	CR	0	0	0	0	0	0	0	1
ALUMINUM, ppm	AL	14	12	12	18	20	17	10	11
NICKEL, ppm	NI	25	36	35	21	24	24	18	53
SILVER, ppm	AG	0	0	0	0	0	0	1	1
TIN, ppm	SN	0	3	3	3	3	4	5	7
SILICON, ppm	SI	20	11	10	15	22	24	10	18
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	13	3	16	3	45	40	16	9
ZINC, ppm	ZN	2	0	0	0	12	1	0	0
CALCIUM, ppm	CA	2	0	1	0	1	1	0	2
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	0	0	0	1	2	2	2	2
TITANIUM, ppm	TI	1	0	0	4	9	5	1	3
VANADIUM, ppm	V	70	70	55	48	63	55	120	350
CADMIUM, ppm	CD	0	5	4	0	0	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	89	90	91	92	93	94	95 3/	96
SAMPLE NUMBER CONTROL	LAB NO.	87	94	183	248	148	185	48	111
BUNKERING PORT	WPI	15410	15410	15410	15410	11730	11730	11950	11950
GEOGRAPHICAL REGION	I CODE	4	4	4	4	5	5	5	5
DATE BUNKERED	MO/DAY/YR	7/28/80	4/18/80	9/10/80	9/26/80	6/27/80	7/19/80	7/9/80	6/30/80
CARBON %	C	85.80	85.59	85.37	84.90	85.37	85.50	86.03	86.07
HYDROGEN %	H	10.71	11.15	10.83	10.82	10.92	10.41	12.11	11.29
NITROGEN %	N	0.42	0.36	0.45	0.29	0.27	0.33	0.32	0.19
OXYGEN % (< 0.5%) 1/	O	0.71	0.66	0.68	0.54	0.5	0.5	0.5	0.5
SULFUR %	S	2.46	2.21	2.61	3.36	3.06	3.49	1.61	2.12
ASH %	ASH	0.13	0.05	0.07	0.43	0.08	0.07	0.02	0.05
API GRAVITY @ 60°F 2/	GRAV	13.1	15.7	11.9(12.7)	13.7	14.4(12.7)	11.2	21.1(14.8)	14.2(14.8)
PM FLASH POINT (0°F) 2/	FLASH	186	214	260(206)	202(199)	218	230	202(206)	220(175)
VISCOSITY (SSU @ 100°F)	VISSSU	4410	5100	3266	4118	3360	4387	245	4556
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	3866	4471	2863	3610	2946	3846	210	3994
HEATING VALUE BTU/LB	HTVAL	18290	18790	18400	18390	18160	18610	18210	18346
SPECIFIC WEIGHT LB/GAL	SPECWT	8.15	8.00	8.22	8.12	8.09	8.26	7.74	8.10
PHOSPHORUS, ppm (< 30 ppm) 1/	P	30	30	30	30	30	30	40	30
IRON, ppm	FE	5	4	6	2	10	5	1	4
LEAD, ppm	PB	2	2	2	2	2	1	0	2
COPPER, ppm	CU	1	1	1	0	2	0	0	0
CHROMIUM, ppm	CR	0	0	1	0	0	0	0	0
ALUMINUM, ppm	AL	16	13	7	13	13	12	10	10
NICKEL, ppm	NI	49	38	34	19	28	23	35	52
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	4	4	4	2	1	3	3	7
SILICON, ppm	SI	14	18	10	4	10	9	10	13
BORON, ppm (<15 ppm) 1/	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	11	28	41	14	28	25	2	17
ZINC, ppm	ZN	0	0	2	1	3	0	1	0
CALCIUM, ppm	CA	3	2	13	0	5	4	1	0
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	2	5	14	1	4	3	0	0
TITANIUM, ppm	TI	6	5	10	2	1	1	0	1
VANADIUM, ppm	V	370	290	322	100	89	53	125	210
CADMIUM, ppm	CD	0	0	0	0	0	0	5	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

1/ This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

2/ The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

3/ Not included in statistical analysis because of viscosity.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	37	38	99	100	101	102	103	104
SAMPLE NUMBER CONTROL	LAB NO.	221	166	128	31	233	35	63	239
BUNKERING PORT	WPI	11951	11960	12050	12730	12770	12970	12970	12970
GEOGRAPHICAL REGION	CODE	5	5	5	5	5	5	5	5
DATE BUNKERED	MO/DAY/YR	3/22/80	4/19/80	7/11/80	5/11/80	5/17/80	5/21/80	7/26/80	3/11/80
CARBON %	C	84.91	84.60	85.65	84.56	84.42	85.32	85.54	85.36
HYDROGEN %	H	11.32	11.10	11.21	10.93	10.16	10.87	10.94	10.41
NITROGEN %	N	0.46	0.43	0.38	0.24	0.25	0.36	0.49	0.38
OXYGEN % (< 0.5%)	O	0.63	0.60	0.5	0.5	0.5	0.5	0.5	0.59
SULFUR %	S	2.57	3.29	2.48	2.93	4.58	3.20	2.54	3.24
ASH %	ASH	0.02	0.12	0.10	0.05	0.11	0.04	0.08	0.05
API GRAVITY @ 60°F 2/	GRAV	13.9	15.7	13.3(13.5)	14.2	10.6	13.0	14.4	13.7
PM FLASH POINT (0°F) 2/	FLASH	192	194	174(166)	186(221)	196	198(151)	142	168
VISCOSESS (SSU @ 100°F)	VISSSU	3557	4312	5015	1728	11150	4021	4683	3756
VISCOSESS REDWOOD NO. 1 SEC 3 @ 100°F	VISRWD	3118	3780	4396	1515	9774	3525	4105	3301
HEATING VALUE BTU/LB	HTVAL	18450	18800	18280	17910	18830	18340	18000	19050
SPECIFIC WEIGHT LB/GAL	SPECWT	8.10	8.00	8.16	8.10	8.3	8.17	8.09	8.11
PHOSPHORUS, ppm (< 30 ppm)	P	30	30	30	87	30	70	59	30
IRON, ppm	FE	4	3	7	4	3	5	6	4
LEAD, ppm	PB	1	1	2	0	1	3	1	1
COPPER, ppm	CU	0	1	0	0	0	0	0	0
CHROMIUM, ppm	CR	0	0	0	1	0	1	1	0
ALUMINUM, ppm	AL	11	12	12	9	11	10	10	14
NICKEL, ppm	NI	43	67	53	24	18	56	41	22
SILVER, ppm	AG	0	0	1	0	0	0	0	0
TIN, ppm	SN	4	0	6	0	1	2	3	3
SILICON, ppm	SI	5	6	10	20	6	26	15	6
BORON, ppm (<15 ppm)	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	3	13	16	26	12	11	13	10
ZINC, ppm	ZN	0	1	3	1	1	0	0	1
CALCIUM, ppm	CA	24	1	9	3	0	2	1	0
SARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	1	1	7	4	1	3	1	1
TITANIUM, ppm	TI	3	6	1	6	1	6	6	1
VANADIUM, ppm	V	200	750	380	90	83	400	53	51
CADMIUM, ppm	CD	0	0	0	4	0	1	1	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

1/ This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

2/ The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	105	106	107	108	109	110	111	112
SAMPLE NUMBER CONTROL	LAB NO.	230	246	104	105	102	103	228	262
BUNKERING PORT	WPI	12980	12980	13060	13650	13760	13760	13760	14500
GEOGRAPHICAL REGION	I CODE	5	5	5	5	5	5	5	5
DATE BUNKERED	MO/DAY/YR	3/21/80	3/21/80	4/4/80	3/12/80	7/16/80	7/25/80	3/11/80	10/12/80
CARBON %	C	34.57	34.54	34.91	36.51	36.30	36.58	35.81	36.19
HYDROGEN %	H	10.40	10.51	10.31	10.79	11.61	11.53	12.22	11.10
NITROGEN %	N	0.31	0.10	0.12	0.18	0.27	0.37	0.36	0.24
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.56	0.5	0.5	0.5	0.60	0.78	0.5
SULFUR %	S	4.30	3.36	4.46	2.15	0.79	0.84	0.79	2.25
ASH %	ASH	0.07	0.04	0.10	0.11	0.08	0.01	0.13	0.01
API GRAVITY @ 60°F ^{2/}	GRAV	12.5	12.3	10.0	13.4(13.6)	16.4	17.1(18.2)	18.0	14.6
PM FLASH POINT (0°F) ^{2/}	FLASH	188	184	198	162(153)	260	208(189)	140	202
VISCOSEITY (SSU @ 100°F)	VISSSU	1359	4512	5440	6102	6560	5975	3585	5878
VISCOSEITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	3821	3955	4769	5349	5751	5236	3143	5153
HEATING VALUE BTU/LB	HVAL	18860	18840	17702	18456	18437	18670	18670	18690
SPECIFIC WEIGHT LB/GAL	SPECWT	8.18	8.17	8.35	8.15	7.98	7.93	7.88	8.07
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	30	33	30	30	30	30
IRON, ppm	FE	4	4	6	5	7	5	3	5
LEAD, ppm	PB	1	1	1	3	4	4	3	2
COPPER, ppm	CU	0	0	0	1	2	1	0	0
CHROMIUM, ppm	CR	0	0	0	1	1	0	0	0
ALUMINUM, ppm	AL	10	10	11	13	10	15	10	15
NICKEL, ppm	NI	18	19	30	76	9	6	4	62
SILVER, ppm	AG	0	0	0	1	0	0	0	0
TIN, ppm	SN	2	1	4	7	6	4	0	5
SILICON, ppm	SI	5	4	15	17	13	16	5	6
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	17	18	7	14	28	17	21	8
ZINC, ppm	ZN	1	1	0	0	0	0	1	2
CALCIUM, ppm	CA	0	1	0	4	4	4	2	2
SARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	1	1	0	3	2	3	2	0
TITANIUM, ppm	TI	1	0	1	5	2	6	0	1
VANADIUM, ppm	V	57	55	91	500	25	16	10	160
CAOMIUM, ppm	CB	0	0	0	0	0	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	113	114	115	116	117	118	119	120
SAMPLE NUMBER CONTROL	LAB NO.	134	154	157	136	193	13	9	152
BUNKERING PORT	WPI	13340	31000	31110	31140	34885	33851	37290	37990
GEOGRAPHICAL REGION	I CODE	0	5	6	5	5	5	5	5
DATE BUNKERED	MO/DAY/YR	7/16/80	7/19/80	8/19/80	6/9/80	7/28/80	6/23/80	7/15/80	6/28/80
CARBON %	C	84.86	85.08	86.18	85.52	85.52	85.07	85.07	84.85
HYDROGEN %	H	10.89	11.01	10.43	10.79	11.04	10.50	11.53	11.26
NITROGEN %	N	0.23	0.23	0.31	0.17	0.09	0.34	0.27	0.22
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	3.35	2.58	2.84	3.31	2.99	3.79	3.29	3.61
ASH %	ASH	0.07	0.05	0.09	0.13	0.05	0.14	0.04	0.04
API GRAVITY @ 60°F ^{2/}	GRAV	15.0	13.6(13.4)	11.9	15.1	17.6	10.4(11.0)	15.7(15.4)	15.3
PM FLASH POINT (0°F) ^{2/}	FLASH	255	256 (239)	208	226	160(185)	162 (190)	232 (220)	206
VISCOSITY (SSU @ 100°F)	VISSSU	3340	3655	1980	3942	1084	5394	3259	3307
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	2298	3204	4366	3456	950	4904	2357	1999
HEATING VALUE BTU/LB	HTVAL	18770	19120	18300	19040	18900	18200	18200	18380
SPECIFIC WEIGHT LB/GAL	SPECWT	8.05	8.12	8.23	8.04	7.90	8.32	8.02	8.04
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	30	30	30	33	30	30
IRON, ppm	FE	4	5	13	2	2	16	5	4
LEAD, ppm	PB	0	1	1	0	1	2	0	1
COPPER, ppm	CU	0	0	1	0	0	0	0	1
CHROMIUM, ppm	CR	0	0	0	0	0	0	0	0
ALUMINUM, ppm	AL	4	14	7	5	3	10	7	10
NICKEL, ppm	NI	12	9	23	7	7	37	28	21
SILVER, ppm	AG	0	0	0	0	0	1	0	0
TIN, ppm	SN	0	0	0	0	0	5	2	1
SILICON, ppm	SI	6	4	4	5	5	19	10	7
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	5	12	12	0	7	50	18	12
ZINC, ppm	ZN	1	1	2	1	0	0	0	1
CALCIUM, ppm	CA	0	1	2	0	0	7	1	0
SARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNETIUM, ppm	MG	1	1	1	0	1	1	4	1
TITANIUM, ppm	TI	0	0	3	0	0	2	0	1
VANADIUM, ppm	V	29	20	57	20	18	130	135	94
CAOMIUM, ppm	CD	0	0	0	0	0	0	4	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	101	102	103	104	105	106	107	108
SAMPLE NUMBER CONTROL	LAB NO.	102	92	55	53	115	73	156	61
BUNKERING PORT	API	32390	36860	38775	39130	39130	39470	39470	43320
GEOPGRAPHICAL REGION	I CODE	6	-	-	-	-	-	-	-
DATE BUNKERED	MO/DAY/YR	9/17/80	7/11/80	7/13/80	7/5/80	7/20/80	8/13/80	7/21/80	5/27/80
CARBON %	C	35.07	35.30	35.04	35.72	34.38	34.06	34.45	35.51
HYDROGEN %	H	11.71	10.90	10.44	12.03	11.09	10.35	11.01	11.00
NITROGEN %	N	0.08	0.20	0.08	0.36	0.25	0.29	0.30	0.30
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.95
SULFUR %	S	2.67	2.47	4.05	1.38	3.41	4.19	3.97	3.56
ASH %	ASH	0.05	0.13	0.05	0.07	0.05	0.13	0.17	0.07
API GRAVITY @ 50°F ^{2/}	GRAV	16.7	12.8(13.5)	11.7(11.6)	16.6(18.8)	15.9	15.4(13.6)	13.4	13.1
PM FLASH POINT (0°F) ^{2/}	FLASH	218(203)	254(180)	232(250)	210(212)	258	150(142)	196	148
VISCOSITY (SSU @ 100°F)	VISSSU	1436	5739	6128	2325	1977	3982	3996	3365
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	1259	5031	5572	2038	1733	1702	5415	1950
HEATING VALUE BTU/LB	HTVAL	18740	18360	18250	18660	18222	18420	18480	18350
SPECIFIC WEIGHT LB/GAL	SPECWT	7.95	8.18	8.25	7.97	8.01	8.15	8.15	8.17
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	30	30	30	60	30	30
IRON, ppm	FE	4	7	5	4	11	8	-	19
LEAD, ppm	PB	1	1	2	1	1	2	2	2
COPPER, ppm	CU	1	0	0	0	0	0	1	0
CHROMIUM, ppm	CR	0	0	0	1	0	0	0	1
ALUMINUM, ppm	AL	9	9	10	10	9	10	12	9
NICKEL, ppm	NI	28	20	31	42	30	42	36	24
SILVER, ppm	AG	0	0	0	0	0	1	0	0
TIN, ppm	SN	1	3	2	4	3	3	1	3
SILICON, ppm	SI	5	17	10	10	11	17	9	23
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	27	6	8	15	13	29	11	70
ZINC, ppm	ZN	2	0	1	3	0	0	1	0
CALCIUM, ppm	CA	1	0	1	2	0	0	1	3
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	2	1	0	3	1	2	0	1
TITANIUM, ppm	TI	2	1	0	0	1	2	2	5
VANADIUM, ppm	V	125	68	76	310	98	130	130	76
CAOMIUM, ppm	CD	0	0	6	3	0	0	0	3
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	129	130	131	132	133	134	135	136
SAMPLE NUMBER CONTROL	LAB NO.	100	45	124	105	141	140	243	153
BUNKERING PORT	WPI	46770	46850	46850	46850	46850	46850	46850	48140
GEOGRAPHICAL REGION	I CODE	-	-	-	-	-	-	-	8
DATE BUNKERED	MO/DAY/YR	6/19/80	5/30/80	7/15/80	6/21/80	4/25/80	5/17/80	7/21/80	5/20/80
CARBON %	C	85.55	86.48	85.80	85.54	85.31	86.25	86.29	81.14
HYDROGEN %	H	10.65	10.59	10.25	10.76	10.37	10.10	10.35	11.42
NITROGEN %	N	0.23	0.38	0.33	0.33	0.07	0.23	0.03	0.11
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	5.27	5.17	5.04	5.16	5.04	5.90	2.87	1.35
ASH %	ASH	0.05	0.04	0.11	0.09	0.08	0.10	0.04	0.08
API GRAVITY @ 60°F ^{2/}	GRAV	13.4(13.5)	11.5(11.5)	11.7(11.6)	12.5(13.1)	12.1	11.3	11.5	17.5
PM FLASH POINT (0°F) ^{2/}	FLASH	164 (167)	178 (162)	178 (172)	156 (160)	152	142	166	173
VISCOSITY (SSU @ 100°F)	VISSSU	1501	1386	1918	1779	1566	1529	1492	1179
VISCOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	1516	1215	1861	1560	1373	1340	1308	1054
HEATING VALUE BTU/LB	HTVAL	18486	17980	18520	18140	19860	18580	18480	18300
SPECIFIC WEIGHT LB/GAL	SPECWT	8.15	8.26	8.25	8.18	8.21	8.22	8.24	7.91
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	39	30	36	30	30	30	30	30
IRON, ppm	FE	30	11	19	16	9	9	9	1
LEAD, ppm	PB	1	1	2	4	1	2	3	3
COPPER, ppm	CU	1	0	0	1	0	0	0	1
CHROMIUM, ppm	CR	0	0	0	0	0	0	0	0
ALUMINUM, ppm	AL	13	12	15	19	14	15	15	11
NICKEL, ppm	NI	45	42	53	42	55	26	30	21
SILVER, ppm	AG	0	0	1	0	0	0	0	0
TIH, ppm	SM	3	4	4	5	3	2	3	1
SILICON, ppm	SI	19	18	15	21	8	9	7	4
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	25	3	19	23	13	13	11	5
ZINC, ppm	ZN	2	0	3	2	4	6	3	1
CALCIUM, ppm	CA	0	0	0	1	1	1	1	0
SARIUM, ppm	SA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	2	1	4	3	1	2	1	0
TITANIUM, ppm	TI	2	0	1	5	2	2	2	1
VANADIUM, ppm	V	105	100	130	83	30	59	65	70
CAOMIUM, ppm	CD	0	5	0	0	0	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	137	138	139	140	141	142	143	144
SAMPLE NUMBER CONTROL	LAB NO.	210	215	56	192	202	205	206	205
BUNKERING PORT	WPI	48140	49140	49335	49335	49240	19240	19240	50000
GEOGRAPHICAL REGION	I CODE	8	3	8	3	3	8	8	3
DATE BUNKERED	MO/DAY/YR	8/15/80	8/21/80	6/21/80	6/5/80	3/16/80	3/2/80	5/31/80	5/26/80
CARBON %	C	85.00	84.26	85.17	85.19	84.55	85.01	85.22	84.49
HYDROGEN %	H	10.92	11.96	11.46	11.53	10.95	10.50	10.50	11.51
NITROGEN %	N	0.19	0.09	0.09	0.11	0.24	0.25	0.22	0.18
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.39	0.5	0.5	0.5	0.5	0.5	0.5
SULFUR %	S	3.50	2.65	2.63	2.70	3.80	3.67	3.50	3.71
ASH %	ASH	0.06	0.11	0.12	0.01	0.11	0.01	0.08	0.04
API GRAVITY @ 60°F ^{2/}	GRAV	15.9	10.4	21.1	19.1	14.1(15.5)	14.2	13.9(17.1)	16.3(17.0)
PM FLASH POINT (0°F) ^{2/}	FLASH	186	168	164	162	180 (202)	184	180	148 (291)
VISCOSESSY (SSU @ 100°F)	VISSSU	926	104	357	401	1589	1658	1691	1293
VISCOSESSY REDWOOD NO. 1 SEC @ 100°F	VISRWD	312	354	313	352	1591	1453	1482	1134
HEATING VALUE BTU/LB	HTVAL	13670	18720	18670	18530	18720	13580	18770	13590
SPECIFIC WEIGHT LB/GAL	SPECWT	8.00	7.75	7.74	7.93	8.10	8.09	8.10	7.96
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	35	30	30	30	30	30
IRON, ppm	FE	2	0	2	1	4	4	4	1
LEAD, ppm	PB	1	0	2	1	1	1	1	1
COPPER, ppm	CU	0	0	0	1	0	0	0	1
CHROMIUM, ppm	CR	0	0	0	1	1	0	1	0
ALUMINUM, ppm	AL	10	7	10	7	10	9	8	10
NICKEL, ppm	NI	7	1	5	4	13	14	11	26
SILVER, ppm	AG	0	0	0	0	0	0	0	0
TIN, ppm	SN	0	0	2	0	0	0	1	6
SILICON, ppm	SI	5	2	7	5	6	7	6	14
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	15	15
SODIUM, ppm	NA	4	21	3	3	7	6	6	11
ZINC, ppm	ZN	0	1	1	0	1	1	0	1
CALCIUM, ppm	CA	0	2	1	2	1	0	0	1
BARIUM, ppm	BA	0	0	0	0	0	0	0	0
MAGNESIUM, ppm	MG	0	5	1	2	2	2	1	1
TITANIUM, ppm	TI	0	0	0	0	1	1	1	1
VANADIUM, ppm	V	24	8	16	5	30	29	22	77
CAOMIUM, ppm	CD	0	0	5	0	0	0	0	0
MANGANESE, ppm	MN	0	0	0	0	0	0	0	0

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^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.1 (Cont.)
SAMPLE TEST RESULTS

SAMPLE COUNT REFERENCE	COUNT	145	146	147	148	149	150	
SAMPLE NUMBER CONTROL	LAB NO.	136	151	189	191	187	162	
BUNKERING PORT	WPI	50000	50000	50000	50000	50010	57840	
GEOGRAPHICAL REGION	I CODE	8	8	8	8	8	8	
DATE BUNKERED	MO/DAY/YR	7/4/80	4/8/80	8/30/80	3/2/80	7/28/80	8/15/80	
CARBON %	C	85.07	85.28	84.86	84.74	85.27	85.56	
HYDROGEN %	H	11.38	11.22	11.09	11.10	11.11	11.23	
NITROGEN %	N	0.15	0.18	0.21	0.17	0.14	0.18	
OXYGEN % (< 0.5%) ^{1/}	O	0.5	0.5	0.5	0.5	0.5	0.58	
SULFUR %	S	2.00	3.10	3.58	3.60	3.08	2.00	
ASH %	ASH	0.05	0.01	0.02	0.11	0.02	0.12	
API GRAVITY @ 60°F ^{2/}	GRAV	16.6(17.1)	16.2(16.3)	16.2(16.5)	16.2	16.7	16.1(17.2)	
PM FLASH POINT (0°F) ^{2/}	FLASH	182 (182)	288 (185)	140 (174)	164	142	172 (285)	
VISCOSESS (SSU @ 100°F)	VISSSU	1957	2325	1538	1501	1650	1394	
VISCOSESS REDWOOD NO. 1 SEC @ 100°F	VISRWD	1716	2038	1348	1316	1446	1222	
HEATING VALUE BTU/LB	HTVAL	18200	18580	18530	19440	19220	18040	
SPECIFIC WEIGHT LB/GAL	SPECWT	7.97	7.98	7.98	7.98	7.95	8.00	
PHOSPHORUS, ppm (< 30 ppm) ^{1/}	P	30	30	30	30	30	30	
IRON, ppm	FE	2	4	7	8	2	3	
LEAD, ppm	PB	1	2	1	1	1	2	
COPPER, ppm	CU	1	0	0	0	0	1	
CHROMIUM, ppm	CR	0	0	0	0	0	0	
ALUMINUM, ppm	AL	11	13	15	16	3	10	
NICKEL, ppm	NI	20	8	11	10	7	13	
SILVER, ppm	AG	0	0	0	0	0	0	
TIN, ppm	SN	3	2	0	0	0	0	
SILICON, ppm	SI	2	8	4	4	5	4	
BORON, ppm (<15 ppm) ^{1/}	B	15	15	15	15	15	15	
SODIUM, ppm	NA	14	16	16	13	7	12	
ZINC, ppm	ZN	2	0	1	2	0	3	
CALCIUM, ppm	CA	2	0	0	0	0	0	
BARIUM, ppm	BA	0	0	0	0	0	0	
MAGNESIUM, ppm	MG	3	2	1	1	1	1	
TITANIUM, ppm	TI	2	3	1	0	0	1	
VANADIUM, ppm	V	74	25	26	24	16	49	
CADMIUM, ppm	CD	0	0	0	0	0	0	
MANGANESE, ppm	MN	0	0	0	0	0	0	

^{1/} This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

^{2/} The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.2
CUMULATIVE SAMPLE RESULTS BY TEST AND REGION

		GEOGRAPHIC AREA				TEST				TEST	
		1	2	3	4	5	6	7	8	9	10
GRAY	MIN	9.90	10.00	9.70	10.00	10.60	10.40	11.50	11.90	8.70	
	MAX	17.10	15.00	15.90	15.70	16.00	17.60	16.60	21.10	21.10	
	AVG	13.68	11.69	12.62	13.29	14.06	14.30	13.05	16.73	13.53	
	SIG	1.74	1.14	1.79	1.41	1.93	2.33	1.60	2.11	2.14	
VISSU	MIN	869.00	1511.00	1746.00	926.00	1728.00	1084.00	1386.00	357.00	357.00	
	MAX	7655.00	11130.00	6037.00	9538.00	11150.00	6128.00	5739.00	2325.00	11150.00	
	AVG	4370.70	4082.70	1744.00	4666.76	4949.76	3672.50	2427.31	1324.20	3967.77	
	SIG	1583.06	1926.96	1069.85	1689.62	1971.96	1620.07	1260.99	560.72	1676.04	
VISRD	MIN	761.79	1324.58	1530.58	811.75	1514.81	950.26	1215.00	312.55	312.95	
	MAX	6710.55	9756.82	5292.18	8361.23	9776.35	5371.95	5030.94	2030.15	9774.35	
	AVG	3631.45	3585.13	4158.70	4090.99	6339.08	3219.69	2127.53	1160.02	3478.24	
	SIG	1387.75	1690.97	937.85	1481.16	1728.65	1428.19	1122.94	500.07	1644.59	
FLASH	MIN	134.00	156.00	154.00	144.00	140.00	160.00	142.00	140.00	134.00	
	MAX	262.00	258.00	220.00	266.00	260.00	256.00	259.00	268.00	268.00	
	AVG	186.27	196.89	193.35	226.91	190.82	215.50	180.92	162.53	195.99	
	SIG	30.24	28.96	17.09	32.54	29.96	33.25	36.61	36.12	33.65	
HIVAL	MIN	17950.00	17850.00	17940.00	17792.00	17910.00	18208.00	17488.00	18040.00	17702.00	
	MAX	16920.00	19050.00	18720.00	18790.00	19050.00	19128.00	18668.00	19220.00	19220.00	
	AVG	16352.82	16315.00	18369.50	16298.33	16543.47	16640.00	18302.92	16606.00	16404.93	
	SIG	242.83	324.40	239.62	266.86	308.73	336.22	239.50	267.47	293.87	
SPECWT	MIN	7.93	6.05	8.00	8.00	7.80	7.90	7.97	7.74	7.76	
	MAX	8.34	6.35	8.42	8.35	8.30	8.32	8.26	8.10	8.42	
	AVG	6.13	6.26	8.19	8.15	8.10	8.09	8.16	7.96	8.16	
	SIG	6.10	6.06	8.10	8.08	8.11	8.14	8.09	0.11	0.12	
C	MIN	84.20	85.31	84.73	84.59	84.42	86.05	84.06	84.26	84.06	
	MAX	87.39	86.79	87.46	86.69	86.80	86.18	86.48	85.56	87.46	
	AVG	86.02	86.07	86.21	85.86	85.51	85.23	85.51	84.95	85.77	
	SIG	0.66	0.63	0.68	0.63	0.70	0.41	0.71	0.37	0.72	
H	MIN	10.10	10.02	10.28	10.31	10.16	10.30	10.10	10.50	10.02	
	MAX	11.31	11.18	11.22	11.64	12.22	11.71	12.03	11.96	12.22	
	AVG	10.82	10.57	10.84	10.91	10.99	10.74	10.76	11.23	10.86	
	SIG	0.38	0.30	0.25	0.33	0.53	0.47	0.49	0.43	0.42	
H	MIN	0.22	0.05	0.30	0.12	0.01	0.00	0.03	0.09	0.01	
	MAX	0.36	0.39	0.82	0.46	0.49	0.36	0.58	0.25	0.82	
	AVG	0.37	0.26	0.63	0.33	0.31	0.20	0.25	0.17	0.34	
	SIG	0.10	0.08	0.13	0.09	0.12	0.09	0.11	0.05	0.16	

TABLE 2.2 (Cont.)
CUMULATIVE SAMPLE RESULTS BY TEST AND REGION

Geographic Area								TOT
	1	2	3	4	5	6	7	8
0	MIN	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	MAX	0.67	0.56	1.31	0.71	0.76	0.50	1.95
	AVG	0.53	0.53	0.64	0.53	0.56	0.50	0.53
	SIG	0.05	0.10	0.24	0.07	0.08	0.10	0.16
5	MIN	1.02	1.71	1.10	1.96	0.79	2.38	1.00
	MAX	4.30	3.65	2.90	4.46	4.58	4.03	4.05
	AVG	2.36	2.71	1.76	2.63	2.68	3.23	3.22
	SIG	0.67	0.44	0.64	0.66	1.16	0.51	0.75
ASH	MIN	0.02	0.01	0.01	0.01	0.01	0.04	0.01
	MAX	0.20	0.19	0.24	0.13	0.13	0.14	0.12
	AVG	0.09	0.07	0.07	0.06	0.07	0.07	0.07
	SIG	0.04	0.04	0.06	0.03	0.04	0.04	0.04
FE	MIN	1.00	1.00	4.00	2.00	3.00	2.00	4.00
	MAX	21.00	14.00	64.00	16.00	7.00	16.00	30.00
	AVG	6.12	2.00	30.05	6.01	4.59	6.00	12.23
	SIG	5.65	4.66	13.42	3.31	1.23	4.67	7.05
P3	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX	13.00	3.00	29.00	3.00	4.00	2.00	4.00
	AVG	2.91	1.23	4.70	1.24	1.82	0.90	1.77
	SIG	2.78	0.79	6.41	0.94	1.19	0.74	0.93
CU	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX	2.00	1.00	2.00	2.00	2.00	1.00	2.00
	AVG	0.64	0.39	0.45	0.52	0.29	0.36	0.33
	SIG	0.65	0.47	0.60	0.60	0.59	0.46	0.49
CR	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	AVG	0.52	0.50	0.49	0.24	0.29	0.00	0.20
	SIG	0.51	0.51	0.50	0.44	0.47	0.00	0.47
AL	MIN	7.00	2.00	7.00	6.00	9.00	3.00	9.00
	MAX	23.00	10.00	20.00	20.00	15.00	14.00	19.00
	AVG	12.79	11.70	11.60	12.43	11.41	7.90	12.15
	SIG	3.14	2.87	3.72	3.68	1.87	3.35	2.88
NJ	MIN	14.00	12.00	36.00	19.00	4.00	7.00	20.00
	MAX	81.00	51.00	103.00	53.00	76.00	37.00	53.00
	AVG	44.12	27.79	74.15	32.29	34.88	20.70	35.92
	SIG	21.50	12.45	17.54	8.61	22.82	11.27	9.52

TABLE 2.2 (Cont.)
CUMULATIVE SAMPLE RESULTS BY TEST AND REGION

TEST	GEOGRAPHIC AREA					6	7	8	9	10
	1	2	3	4	5					
AG	MIN 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX 1.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
	Avg 0.03	0.00	0.00	0.10	0.10	0.10	0.15	0.00	0.05	0.05
	SIG 0.17	0.00	0.00	0.30	0.33	0.32	0.38	0.00	0.23	
SN	MIN 0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
	MAX 7.00	5.00	6.00	7.00	7.00	5.00	5.00	6.00	7.00	7.00
	Avg 3.12	2.00	2.40	2.76	3.10	1.10	3.15	1.00	2.50	
	SIG 2.10	1.45	1.73	1.74	2.40	1.60	0.99	1.67	1.93	
SI	MIN 3.00	3.00	4.00	4.00	4.00	4.00	7.00	2.00	2.00	2.00
	MAX 26.00	30.00	35.00	24.00	26.00	19.00	23.00	16.00	35.00	
	Avg 16.39	17.30	15.00	13.86	10.71	7.50	14.15	5.53	13.42	
	SIG 6.69	9.44	6.50	6.72	6.38	4.60	5.40	2.90	7.67	
8	MIN 15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
	MAX 15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
	Avg 15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
	SIG 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NA	MIN 0.00	1.00	0.00	3.00	3.00	0.00	3.00	3.00	3.00	3.00
	MAX 35.00	21.00	43.00	45.00	28.00	50.00	70.00	44.25	70.00	
	Avg 11.52	7.65	14.40	15.62	15.02	15.10	20.00	11.60	13.45	
	SIG 6.26	4.21	11.69	12.98	6.25	14.31	16.70	10.47	19.59	
P	MIN 30.00	30.00	38.00	36.00	38.00	30.00	30.00	30.00	30.00	30.00
	MAX 165.00	310.00	256.00	71.00	67.00	70.00	60.00	35.00	310.00	
	Avg 40.45	66.40	60.15	35.95	37.39	36.30	31.46	30.33	45.10	
	SIG 33.00	76.19	55.15	12.15	17.18	13.87	6.47	1.29	49.14	
ZN	MIN 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX 10.00	4.00	39.00	12.00	5.00	2.00	6.00	3.00	39.00	
	Avg 2.39	0.00	5.65	1.14	0.71	0.90	1.95	0.93	1.05	
	SIG 3.06	1.06	10.01	2.63	0.93	0.74	1.91	0.86	4.36	
CA	MIN 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX 18.00	21.00	57.00	13.00	24.00	7.00	3.00	2.00	57.00	
	Avg 5.15	4.55	16.00	1.76	1.59	1.30	0.77	0.60	4.61	
	SIG 6.44	6.25	13.99	2.91	5.73	2.11	0.93	0.63	7.95	
SA	MIN 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAX 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	Avg 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2.2 (Cont.)
CUMULATIVE SAMPLE RESULTS BY TEST AND REGION

	1	2	3	4	5	6	7	8	9	10
ME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MIN	7.00	3.00	6.00	14.00	7.00	4.00	4.00	4.00	3.00	14.00
MAX	2.49	1.45	2.75	2.18	2.00	1.20	1.69	1.53	2.02	
AVG	1.70	1.05	2.24	3.05	1.73	1.14	1.11	1.25	1.89	
SIG										
VI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MIN	10.00	11.00	10.00	10.00	6.00	3.00	3.00	3.00	11.00	
MAX	2.97	2.49	2.55	3.71	2.76	0.89	1.92	0.80	2.46	
AVG	2.97	2.68	2.95	2.94	2.64	1.14	1.55	0.86	2.62	
SIG										
V	MIN	27.00	36.00	32.00	48.00	10.00	15.00	59.00	5.00	5.00
MAX	600.00	345.00	150.00	370.00	750.00	135.00	310.00	770.00	750.00	
AVG	249.49	213.00	95.45	143.33	192.53	70.40	110.31	335.00	141.93	
SIG	138.15	86.75	31.09	102.53	207.94	47.70	64.96	23.38	142.06	
CD	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	5.00	10.00	13.00	6.00	4.00	6.00	5.00	5.00	13.00	
AVG	2.00	2.05	3.25	1.19	0.35	1.00	0.65	0.33	1.64	
SIG	2.35	3.95	4.04	2.20	1.00	2.16	1.66	1.29	2.77	
MN	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
AVG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SIG	0.00									

TABLE 2.3
COMPARISON OF 1980 SURVEY TO 1976 SURVEY
AND THE INDUSTRY REFERENCE 1/

Fuel Characteristics	Symbol	Industry Standard	1976 Survey	1980 Survey
CARBON %	C	87.75	85.20	85.78
HYDROGEN %	H	10.50	11.30	10.88
NITROGEN %	N	0.15	0.80	0.33
OXYGEN % (<0.5%) ^{2/}	O	0.40	0.43	0.55
SULFUR %	S	1.20	2.97	2.60
ASH %	ASH	--	0.03	0.08
API GRAVITY @ 60°F	GRAV	--	15.1	13.65
PM FLASH POINT (0°F)	FLASH	--	192	197
VISCOSEITY (SSU @ 100°F)	VISSU	--	3264	3982
VISCOSEITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	--	2861	3491
HEATING VALUE BTU/LB	HTVAL	18500	18780	18408
SPECIFIC WEIGHT LB/GAL	SPECWT	--	8.99	8.13
PHOSPHORUS, ppm (<30) ^{2/}	P	--	40	46
IRON, ppm	FE	--	6	10
LEAD, ppm	PB	--	1	2
COPPER, ppm	CU	--	0	0.5
CHROMIUM, ppm	CR	--	0	0.4
ALUMINUM, ppm	AL	--	2	12
NICKEL, ppm	NI	--	18	37
SILVER, ppm	AG	--	0	0
TIN, ppm	SN	--	0	3
SILICON, ppm	SI	--	2	13
BORON, ppm (<15) ^{2/}	B	--	0	15
SODIUM, ppm	NA	--	15	13
ZINC, ppm	ZN	--	0	2
CALCIUM, ppm	CA	--	30	5
BARIUM, ppm	BA	--	40	0
MAGNESIUM, ppm	MG	--	180	2
TITANIUM, ppm	TI	--	.2	2
VANADIUM, ppm	V	--	42	140
CADMIUM, ppm	CD	--	0	2
MANGANESE, ppm	MN	--	0	0

1/ The industry reference is for heat balance purposes and is taken from the Society of Naval Architects and Marine Engineers (SNAME) Technical and Research Bulletin 3 - 11, SNAME, 1972.

2/ These averages for oxygen, phosphorus, and boron are artificially high because the quantities indicated were used to represent any sample that fell below these test limits.

TABLE 2.4
MULTIPLIERS FOR 95% CONFIDENCE INTERVAL ^{1/}

Region Code	No. of Samples	t or z ^{2/} Value	Multiplier
1	33	1.645	.29
2	20	2.093	.47
3	20	2.093	.47
4	19	2.101	.48
5	19	2.101	.48
6	9	2.306	.77
7	14	2.160	.58
8	15	2.145	.55
Total	149	1.645	.13

1/ Information from Standard Mathametical Tables,
15th Edition, Chemical Rubber Company, Cleveland
Ohio, 1967.

2/ The t value is taken from the table of sample
distribution probabilities and is used when the
sample size is less than 30. The z value is
also from a table of sample distribution proba-
bilities and is used when the sample size exceeds
30.

20

16

12

8

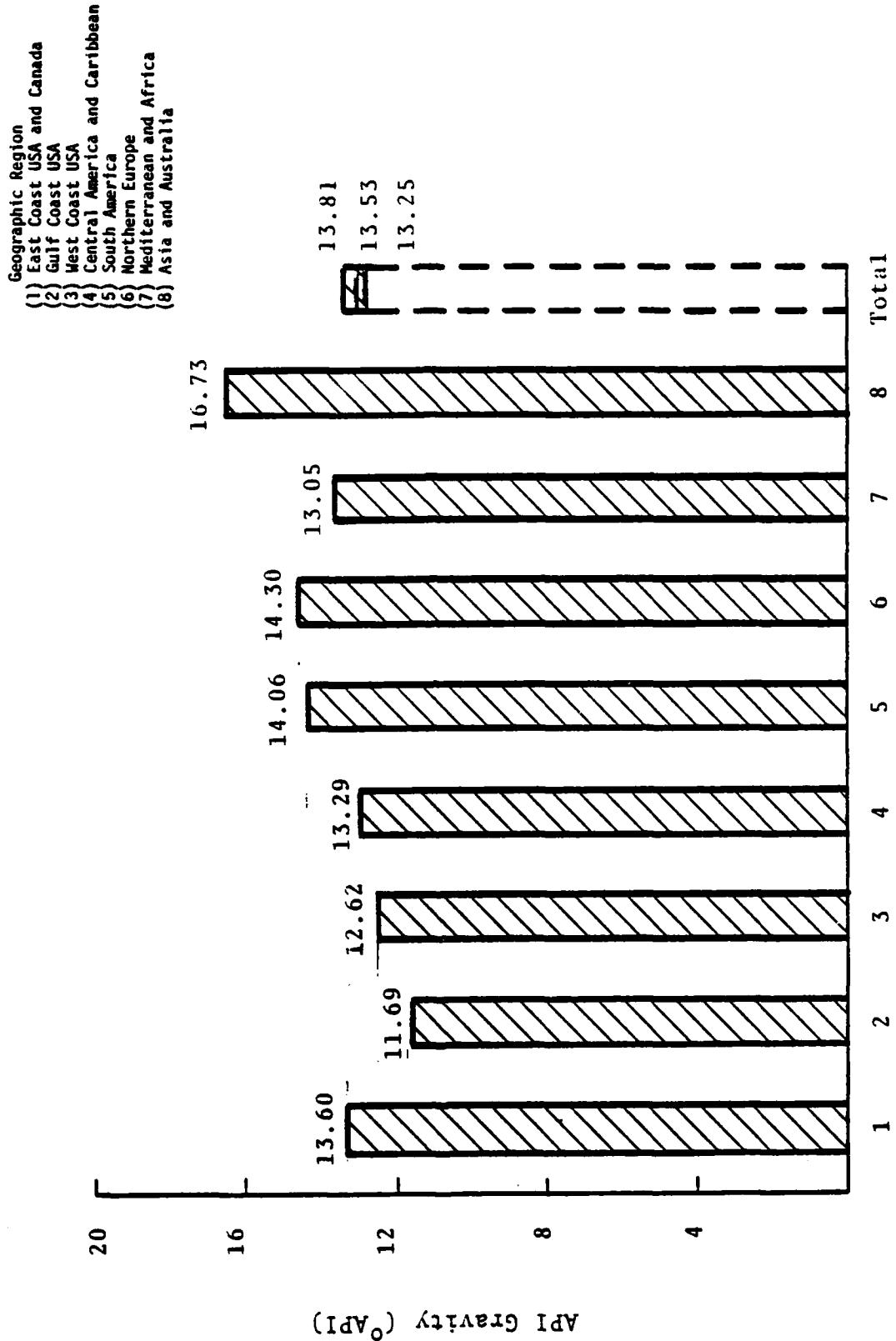
4

1

Region

FIGURE 2.1

AVERAGE API GRAVITY BY GEOGRAPHIC REGION



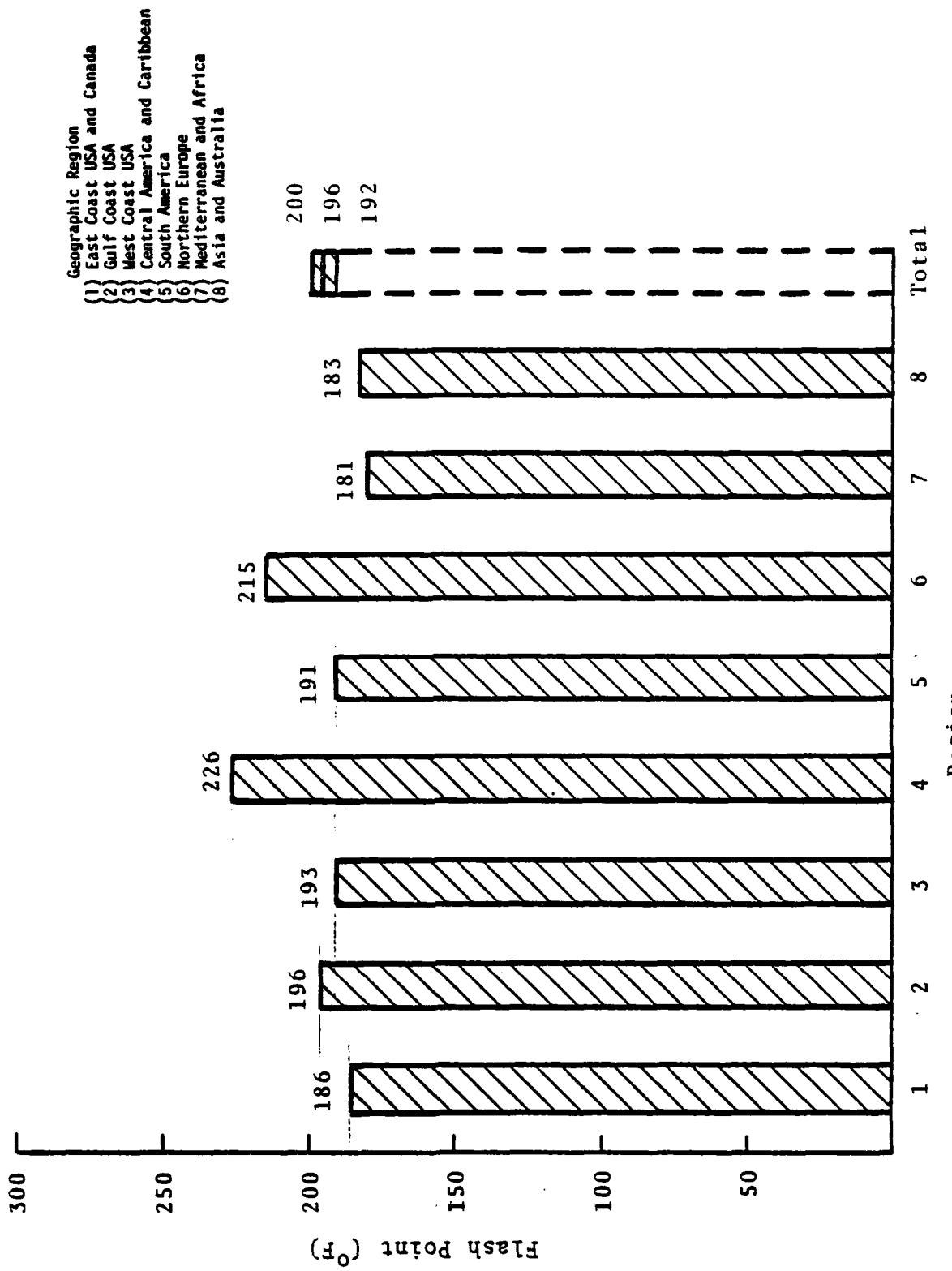


FIGURE 2.2
 AVERAGE FLASH POINT BY GEOGRAPHIC REGION

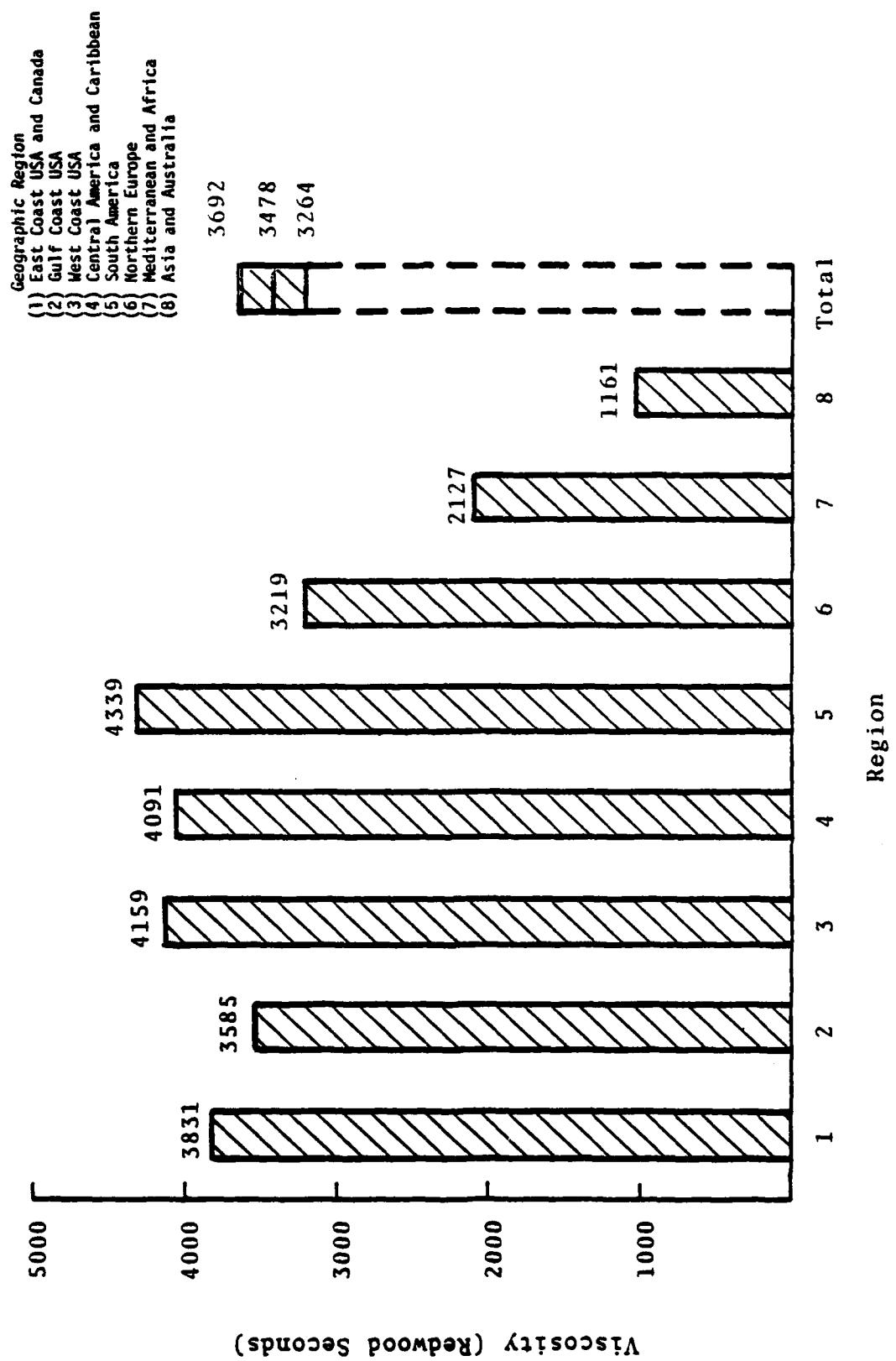


FIGURE 2.3
 AVERAGE VISCOSITY (REDWOOD) BY GEOGRAPHIC REGION

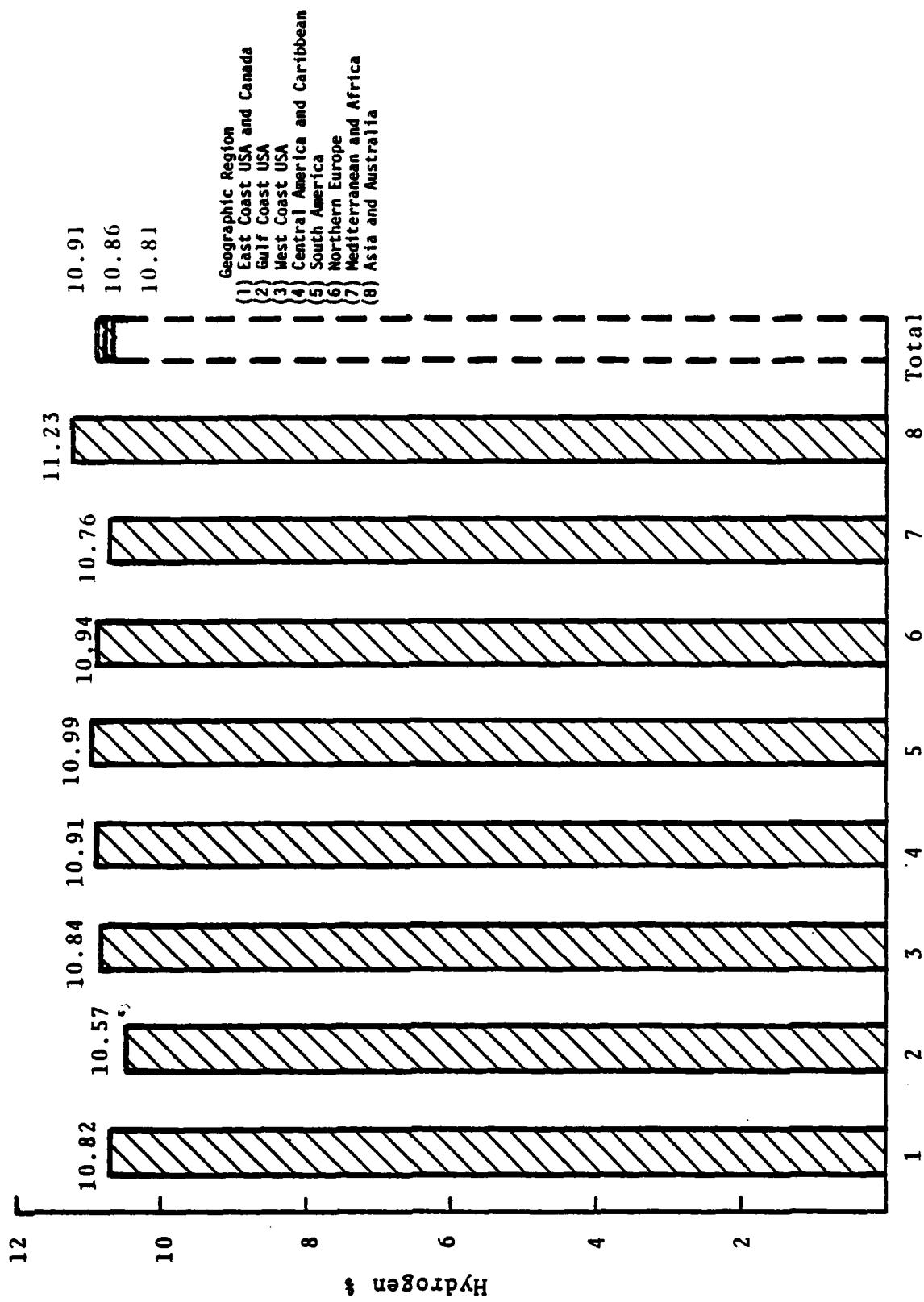


FIGURE 2.4
 AVERAGE HYDROGEN BY GEOGRAPHIC REGION

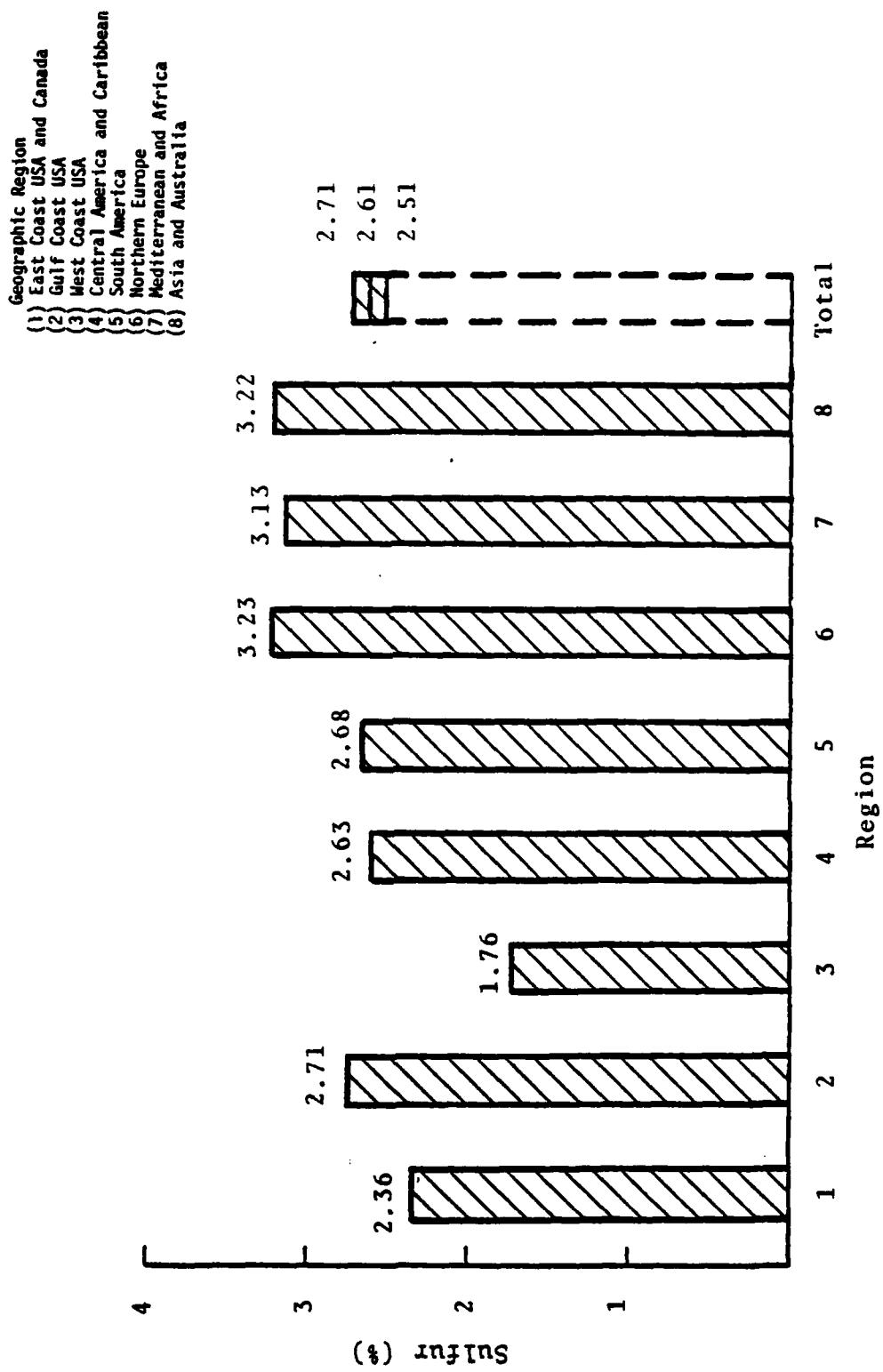


FIGURE 2.5
 AVERAGE SULFUR BY GEOGRAPHIC REGION

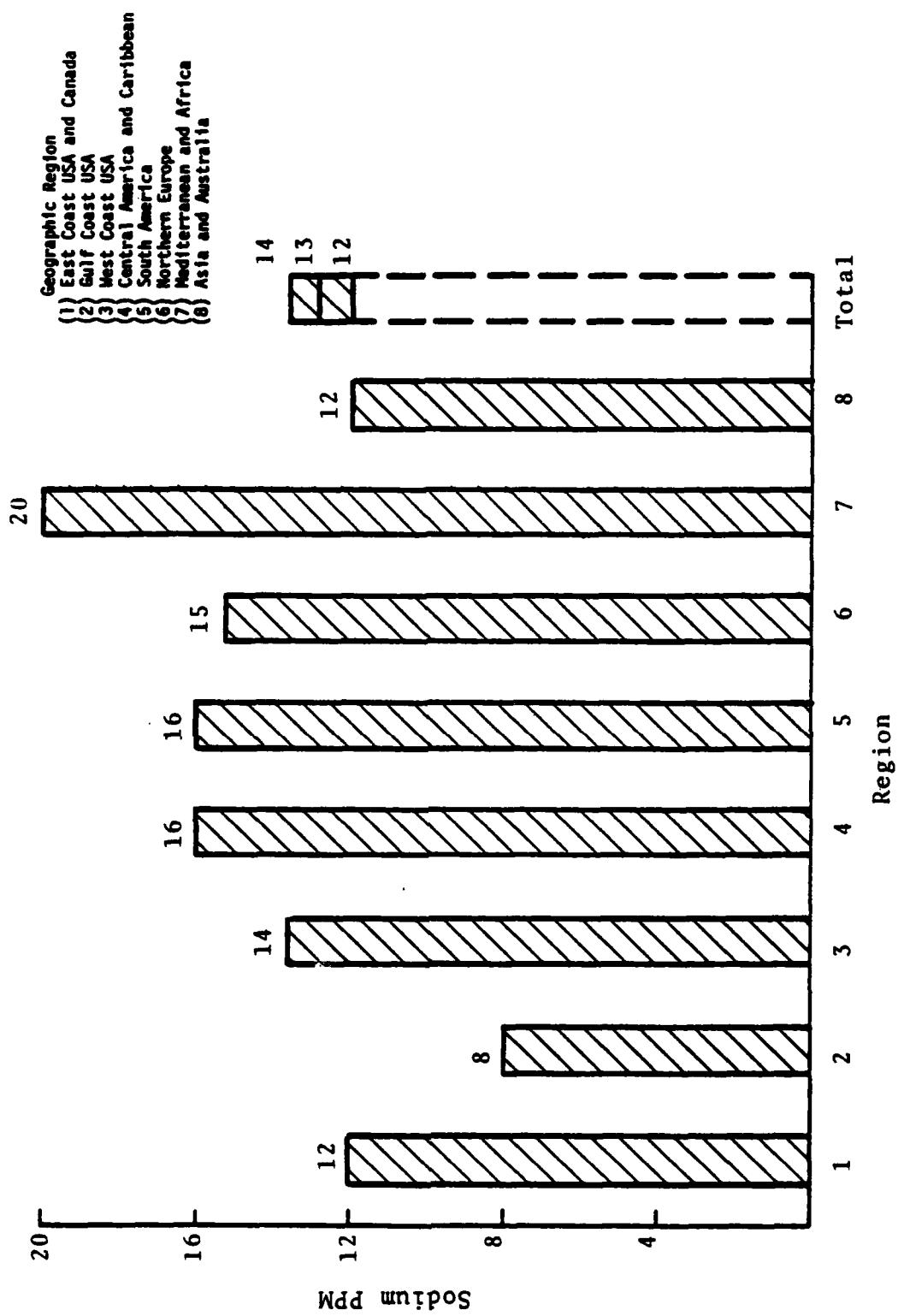


FIGURE 2.6
 AVERAGE SODIUM BY GEOGRAPHIC REGION

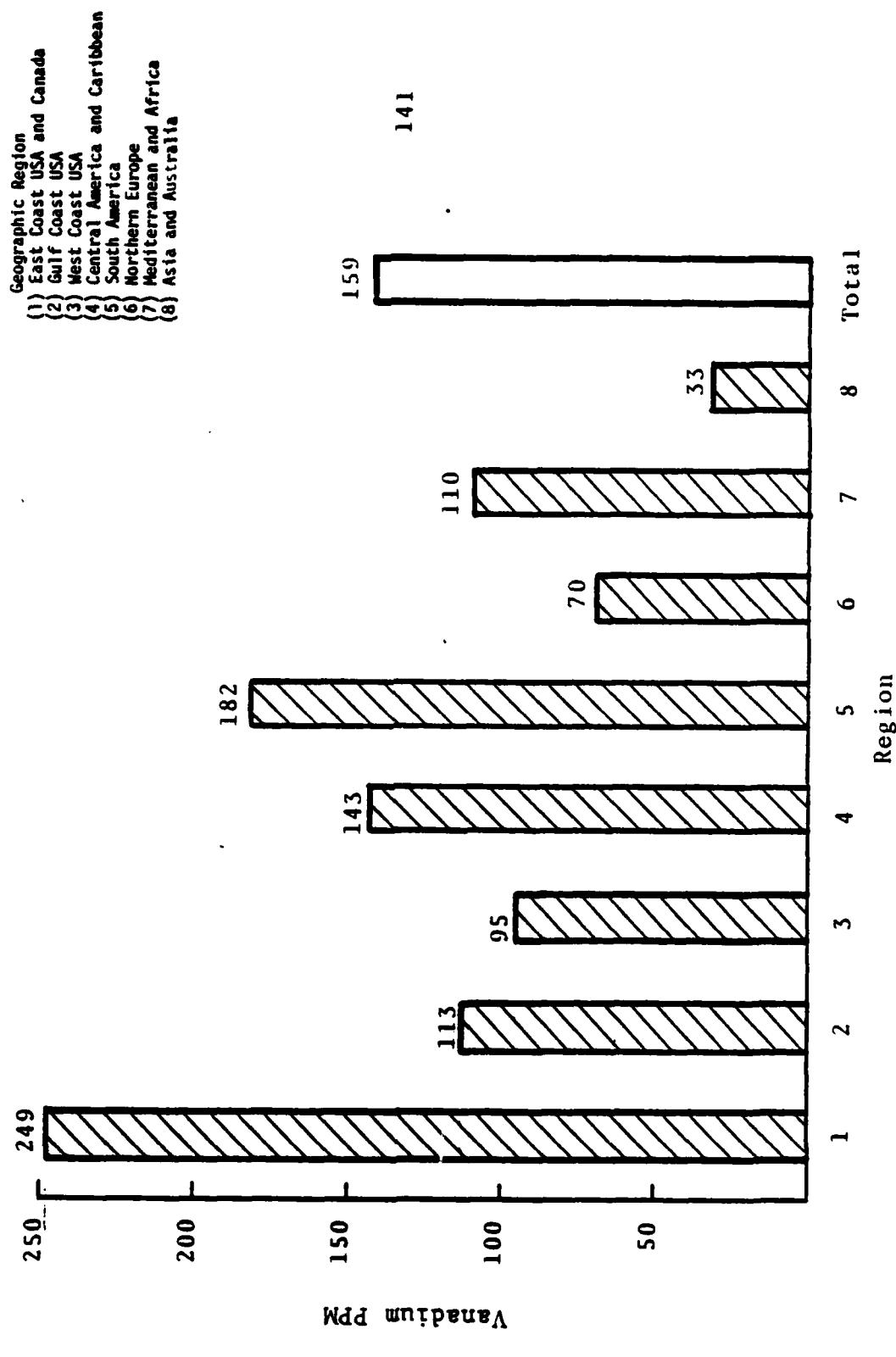


FIGURE 2.7
 AVERAGE VANADIUM BY GEOGRAPHIC REGION

TABLE 2.5
WATCH SAMPLE RESULTS

SAMPLE COUNT REFERENCE	COUNT	4-1	4-2	4-3	4-4	4-5	4-6	
SAMPLE NUMBER CONTROL	LAB NO.	270	271	272	180	204	237	
BUNKERING PORT	WPI	N/A	N/A	N/A	38860	39240	38210	
GEOGRAPHICAL REGION	I CODE	7	7	7	2	3	1	
DATE BUNKERED	MO/DAY/YR	N/A	N/A	N/A	3/10/80	3/11/80	3/6/80	
CARBON %	C	34.68	34.98	35.59	36.40	34.86	36.52	
HYDROGEN %	H	11.45	10.68	11.06	10.77	11.18	10.66	
NITROGEN %	N	0.24	0.25	0.24	0.28	0.24	0.30	
OXYGEN % (< 0.5%)	O	0.50	0.50	0.50	0.50	0.50	0.50	
SULFUR %	S	3.70	3.87	3.18	1.96	3.68	2.82	
ASH %	ASH	0.03	0.04	0.04	0.08	0.09	0.13	
API GRAVITY @ 60°F	GRAV	13.7	13.7	13.5(14.6)	11.5	14.5	11.7	
9M FLASH POINT (0°F)	FLASH	196	220	278(241)	192	188(202)	178	
VISCOOSITY (SSU @ 100°F)	VISSU	2780	3100	3480	4750	1850	4250	
VISCOOSITY REDWOOD NO. 1 SEC @ 100°F	VISRWD	2430	2710	3040	4149	1616	3713	
HEATING VALUE BTU/LB	HTVAL	18620	18170	18320	18020	18020	18040	
SPECIFIC WEIGHT LB/GAL	SPECWT	8.13	8.13	8.14	8.26	8.09	8.25	
PHOSPHORUS, ppm (< 30 ppm)	P	30	30	30	30	30	30	
IRON, ppm	FE	2	2	5	17	7	12	
LEAD, ppm	PB	1	1	1	4	0	1	
COPPER, ppm	CU	1	1	1	1	0	1	
CHROMIUM, ppm	CR	0	0	0	0	0	0	
ALUMINUM, ppm	AL	14	14	10	14	16	10	
NICKEL, ppm	NI	26	27	18	58	18	30	
SILVER, ppm	AG	0	0	0	0	0	0	
TIN, ppm	SN	3	2	2	2	1	2	
SILICON, ppm	SI	8	8	11	21	8	14	
BORON, ppm (<15 ppm)	B	15	15	15	15	15	15	
SODIUM, ppm	NA	12	14	20	15	9	5	
ZINC, ppm	ZN	4	3	2	3	0	0	
CALCIUM, ppm	CA	9	8	0	13	0	1	
SARIUM, ppm	BA	0	0	0	0	0	0	
MAGNESIUM, ppm	MG	1	1	1	3	5	1	
TITANIUM, ppm	TI	3	1	1	2	1	1	
VANADIUM, ppm	V	72	74	48	79	72	220	
CADMIUM, ppm	CD	0	0	0	0	0	0	
MANGANESE, ppm	MN	0	0	0	0	0	0	

1/ This value represents the lowest measurable quantity detectable using ASTM or spectrophotometric test procedures.

2/ The number on the right in parenthesis reflects the reported value from the supplier to the steamship company.

TABLE 2.6
REFERENCES

1. Improved Marine Boiler Reliability, April 1976, Maritime Administration Report No. MA-RD-920-76040, National Technical Information Services PB-252 675, April 1976, prepared by Combustion Engineering Marine Power Systems.
2. Marine Engineering, Society of Naval Architects and Marine Engineers (SNAME), New York, 1971.
3. 1974 Annual Book of ASTM Standards, Part 23, "Petroleum Products and Lubricants (I)."
4. Marine Steam Power Plant Heat Balance Practices, Technical and Research Bulletin 3-11, SNAME, 1972.
5. Quality Control and Industrial Statistics, A. J. Duncan, 3rd Edition, Richard D. Irwin, Inc., Homewood, Illinois, 1965.
6. Standard Mathematical Tables, 15th Edition, The Chemical Rubber Company, Cleveland, Ohio, 1967.

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